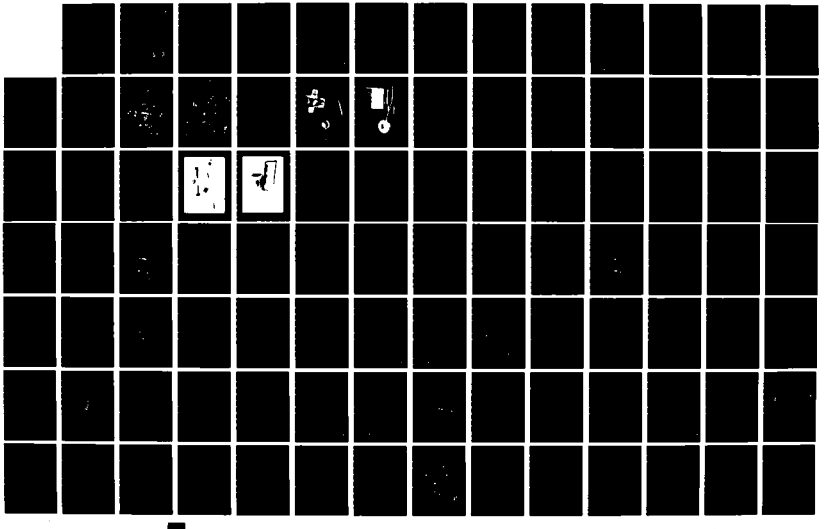
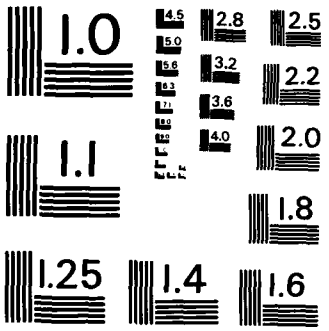
AD-A158 360 ELF (EXTREMELY LOW FREQUENCY) COMMUNICATIONS SYSTEM ECOLOGICAL MONITORING..(U) IIT RESEARCH INST CHICAGO IL R M BROSH ET AL. JUN 85 IITRI-E06549-14 1/2

UNCLASSIFIED N00039-84-C-0070 F/G 6/18 NL





MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS - 1963 - A

(2)

Technical Report E06549-14
Contract No. N00039-84-C-0070

IITRI

AD-A158 360

ELF COMMUNICATIONS SYSTEM ECOLOGICAL MONITORING PROGRAM: MEASUREMENTS OF ELF ELECTROMAGNETIC FIELDS FOR SITE SELECTION AND CHARACTERIZATION - 1984

R. M. Brosh
J. R. Gauger
J. E. Zapotosky

June 1985

Prepared for:

Communications Systems Project Office
Space and Naval Warfare Systems Command
Washington, D.C. 20363

DTIC
ELECTE
AUG 2 8 1985
S D
B

Submitted by:

IIT Research Institute
10 W. 35th Street
Chicago, Illinois 60616

DISTRIBUTION STATEMENT A
Approved for public release;
Distribution Unlimited

DTIC FILE COPY

85 8 23 001

Printed in the United States of America

This report is available from:

National Technical Information Service
U.S. Department of Commerce
5285 Port Royal Road
Springfield, Va. 22161

UNCLASSIFIED
SECURITY CLASSIFICATION OF THIS PAGE

AD-A158 360

REPORT DOCUMENTATION PAGE

1a. REPORT SECURITY CLASSIFICATION Unclassified	1b. RESTRICTIVE MARKINGS
2a. SECURITY CLASSIFICATION AUTHORITY	3. DISTRIBUTION/AVAILABILITY OF REPORT Distribution unlimited Approved for public release Distribution Unlimited
2b. DECLASSIFICATION/DOWNGRADING SCHEDULE NA/NA	
4. PERFORMING ORGANIZATION REPORT NUMBER(S) E06549-14	5. MONITORING ORGANIZATI...
6a. NAME OF PERFORMING ORGANIZATION IIT Research Institute 6b. OFFICE SYMBOL (If applicable)	7a. NAME OF MONITORING ORGANIZATION
6c. ADDRESS (City, State, and ZIP Code) Chicago, Illinois 60616	7b. ADDRESS (City, State, and ZIP Code)
8a. NAME OF FUNDING/SPONSORING ORGANIZATION Space and Naval Warfare Systems Command 8b. OFFICE SYMBOL (If applicable)	9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER N00039-84-C-0070
8c. ADDRESS (City, State, and ZIP Code) Washington, D.C. 20363	10 SOURCE OF FUNDING NUMBERS PROGRAM ELEMENT NO. / PROJECT NO. / TASK NO. / WORK UNIT ACCESSION NO.

11. TITLE (Include Security Classification)
ELF Communications System Ecological Monitoring Program: Measurements of ELF Electromagnetic Fields for Site Selection and Characterization--1984 (Unclassified)

12. PERSONAL AUTHOR(S)
R. M. Brosh, J. R. Gauger, J. E. Zapotosky

13a. TYPE OF REPORT	13b. TIME COVERED	14. DATE OF REPORT (Year, Month, Day)	15. PAGE COUNT
Technical	FROM ____ TO ____	~~April~~ JUNE 1985	133

16. SUPPLEMENTARY NOTATION

17. COSATI CODES		
FIELD	GROUP	SUB-GROUP

18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)
Extremely Low Frequency, Ecology, Electromagnetic Fields, ELF Communication System, Environmental Studies, ELF Ecological Monitoring Program

19. ABSTRACT (Continue on reverse if necessary and identify by block number)

A long-term program for studying possible effects from the operation of the Navy's ELF Communications System is being conducted on biota and ecosystems components in northwestern Wisconsin and the Upper Peninsula of Michigan. Sixteen general types of organisms from three major ecosystems in the ELF system area are being examined. Formulation of an ELF Ecological Monitoring Program was completed in early 1982 by the Department of the Navy. Monitoring studies were conducted through a peer-reviewed, competitive bidding process in mid-1982, and studies were initiated in late summer of the same year. Beginning in 1983 and continuing during 1984 major activities of the program consisted of characterization of critical aspects of each study, collection of data to validate assumptions made in proposals, and selection of study sites. Measurements of electromagnetic fields at the investigator-selected sites are documented, and the acceptability and status of the sites in light of the electromagnetic exposure criteria are discussed.

20 DISTRIBUTION/AVAILABILITY OF ABSTRACT	21. ABSTRACT SECURITY CLASSIFICATION
☒ UNCLASSIFIED/UNLIMITED ☐ SAME AS RPT. ☐ DTIC USERS	Unclassified
22a. NAME OF RESPONSIBLE INDIVIDUAL	22b. TELEPHONE (Include Area Code) / 22c. OFFICE SYMBOL

DD FORM 1473, 84 MAR — 83 APR edition may be used until exhausted. All other editions are obsolete.

SECURITY CLASSIFICATION OF THIS PAGE
UNCLASSIFIED

FOREWORD

This report documents measurements of extremely low frequency (ELF) electromagnetic fields made in support of the Navy ELF Communications System Ecological Monitoring Program from late 1982 through 1984. Other engineering activities in support of the ecological studies are also described. This work was funded by the Space and Naval Warfare Systems Command, Communications Systems Project Office, under Contract Numbers N00039-81-C-0357 and N00039-84-C-0070, to IIT Research Institute (IITRI). IITRI measurement personnel for 1984 were R. M. Brosh, J. R. Gauger, G. L. Nicholas, and Dr. J. E. Zapotosky. Laboratory studies were conducted by J. O. Enk and S. J. Shelfo.

Respectfully submitted,
IIT RESEARCH INSTITUTE

R. M. Brosh
Assistant Engineer

J. R. Gauger
Senior Engineer

J. E. Zapotosky, Ph.D.
Senior Scientist

Approved:

R. D. Carlson
Program Manager

PREVIOUS PAGE IS BLANK

CONTENTS

CONTENTS (continued)

Accession For
NTIS CRA&I ☑
DTIC TAB ☐
Unannounced ☐
Justification
PER CALL JC
By
Distribution/
Availability Codes
Dist | Avail and/or Special
A-1

DTIC COPY INSPECTED

FIGURES AND TABLES

Figure — Page

Table

1. INTRODUCTION

To assure an understanding of the long-term effects on nearby ecological communities of operating an Extremely Low Frequency (ELF) Communications System, the Space and Naval Warfare Systems Command has established an Ecological Monitoring Program to study select biota and ecological relationships in the vicinity of its transmitting facilities. This program is being conducted in Wisconsin and Michigan under subcontracts to IIT Research Institute (IITRI), which provides overall program management as well as electromagnetic (EM) measurement and engineering support. The Ecological Monitoring Program was initiated in 1982 and is expected to continue for several years.

Since the purpose of the Ecological Monitoring Program is to detect whether ecological effects might result from long-term ELF Communications System operations, it is important that fields produced by ELF antennas are distinguishable from the ambient EM fields at locations selected for studying ecological effects. Criteria for EM exposure have therefore been established as reasonable goals for site selection so that rational interpretations can be made of study results. These criteria are in addition to those required to satisfy the biological aspects of the studies.

This report reviews the EM exposure criteria and measurement protocols, documents the measurement of EM fields at the investigator-selected study sites from late 1982 through 1984, and discusses the acceptability and status of the sites in light of the EM exposure criteria. Special engineering activities carried out in support of the ecological studies are also described.

2. ELF ELECTROMAGNETIC SITE SELECTION CRITERIA

2.1 PAIRED-SITE ELECTROMAGNETIC EXPOSURE RATIOS

The EM fields produced by an ELF communications system can be described briefly as follows:

- a magnetic field, the same in the air and in the earth, that is generated by the current in the antenna element;
- an electric field in the air that is produced as a result of the potential difference between the antenna element and the earth;
- an electric field in the earth that is the sum of those produced by the magnetic field in the earth and by the current flowing in the earth from the buried wire elements of the antenna ground terminals.

The ELF system EM fields in question are centered at a frequency of 76 Hz. Commercial power system transmission and distribution lines generate similar EM fields at a fundamental frequency of 60 Hz. The extremely low frequency EM fields produced by ELF transmitting antennas have intensities in the air and in the earth that approximate those attributable to commercial power systems. Hence, both ELF system and power line frequency fields have been considered in characterizing the EM environment at study sites.

The Ecological Monitoring Program employs paired test and control sites to study the effects of ELF EM fields on biological and ecological parameters. Such paired sites have essentially matched biotic and abiotic characteristics, but purposely dissimilar ELF exposures. To aid investigators in selecting study sites, criteria were established for minimum values of EM field ratios between paired sites. These criteria were incorporated into the original statement of work for the program as follows:

> Control plots shall be selected at locations where electric fields in soil near the surface of the earth produced by the ELF system are on the average at least one order of magnitude and preferably two orders of magnitude less than those at paired test plots. The same relationship shall exist for magnetic field components between test and control plots. Electric and magnetic fields in air and earth produced by other ELF sources (e.g., power lines) shall not differ by

more than one order of magnitude between paired test and control plots, and at test plots should be at least one order of magnitude below the fields produced by the ELF system.

In addition, it is desired that the fields produced by the ELF system at the test site be at least one order of magnitude higher than the 60 Hz fields (e.g., power lines) at the control sites. The above conditions can also be stated mathematically with four statements of inequality:

$$(1) \quad \frac{T\ (ELF)}{C\ (ELF)} \geq 10$$

$$(2) \quad \frac{T\ (ELF)}{T\ (60)} \geq 10$$

$$(3) \quad \frac{T\ (ELF)}{C\ (60)} \geq 10$$

$$(4) \quad 0.1 \leq \frac{T\ (60)}{C\ (60)} \leq 10$$

where: T (ELF) = Test site EM field level due to ELF system
T (60) = Test site EM field level due to power lines
C (ELF) = Control site EM field level due to ELF system
C (60) = Control site EM field level due to power lines.

These ratio criteria and inequalities, if met, will assure that the ELF system EM fields at a test site will dominate its ambient and paired-site EM fields by at least a factor of ten, while also assuring that the paired-site ambient EM fields from power lines will be matched to within a factor of ten or better.

2.2 GEOGRAPHICAL CONSIDERATIONS

Investigators were given maps of the existing Wisconsin and proposed Michigan ELF antenna rights-of-way prior to the start of their field activities, along with information on the intensity of the ELF (76 Hz) EM fields by and near the antenna systems. This information was in the form of computer-generated electric field contour map overlays and curves of the electric and magnetic field intensity variation with distance from the antennas. These materials, although based on simple analytical models, were

judged sufficient to provide investigators with first order site selection guidance with respect to the EM requirements of paired sites.

In addition to the antenna location and analytical calculations, map overlays were provided that indicated the location of power transmission and distribution lines in the areas immediately adjacent to the antenna systems. These data were intended to aid investigators in avoiding sites where excessive 60 Hz EM fields would likely be encountered.

3. ELECTROMAGNETIC FIELD MEASUREMENTS

3.1 SITE LOCATIONS

Each investigator has been responsible for selecting potential field sites that satisfy the biological requirements of his study. During the 1983 field season, IITRI personnel documented the sites initially identified by the investigators and made measurements at selected locations within each site.[1] Calculated ratios of the 1983 EM data indicated several sites that needed relocation to meet the EM exposure criteria. Other sites were deemed unacceptable because of nearby logging activities or other biotic factors. During the weeks of 14 to 18 May and 21 to 25 May 1984, IITRI field crews made measurements at and documented 18 new study sites requested by the investigators prior to the start of the 1984 field season. These included a site for a new study of bird migration.

The annual EM field measurements were conducted by IITRI field crews during the weeks of 6 to 10 August, 13 to 17 August, and 20 to 24 August in Michigan and during the weeks of 17 to 21 September and 15 to 19 October in Wisconsin. During this time, all previously measured sites that were still active were remeasured, and one new site each was added for the small mammal, soil amoeba, and wetland studies. In addition, a tenth study group, bird species and communities, was established. Twenty transects, ten in Michigan and ten in Wisconsin, were documented and measured for this study.

Table 1 presents a summary of the number of sites and corresponding measurement locations for 1984. As shown in the table, a total of 183 measurement locations were needed to characterize 72 test and control sites. The number of measurement locations was determined based on plot size and other factors such as the EM environment in the area. In the case of the wetland study, the number of measurement locations per site was determined by the investigator on the basis of the statistical needs of the study.

PREVIOUS PAGE IS BLANK

Exposure chambers with circuitry to control and adjust electric field and current density in the slime mold culture chambers will be installed at the study sites in early 1985. This equipment will allow the fields and currents in the culture chambers to be matched to those in the surrounding soil.

4.2.8 Wetland Studies

Nine wetland study sites were carried over from 1983. Two other sites were replaced in 1984: a test site was replaced for biotic reasons and a control site because of nearby logging. These studies employ a gradient design for their ELF EM exposure, with five test sites (three overhead antenna and two ground terminal), three intermediate sites, and three control sites. Only pairings of test and control sites, however, were used to compute EM field ratios. All possible pairings of test and control sites were either acceptable or conditionally acceptable. No further site selection is anticipated.

4.2.9 Bird Migration Studies

This study will use radar to track the paths of migrating birds near ELF antenna elements. For this reason no paired sites are employed. The 60 Hz EM fields at the radar site were measured twice in 1984, both before and after placement of the radar equipment. These measurements represent 60 Hz EM fields generated primarily by the three phase power line feeding the radar equipment and the equipment itself. The 60 Hz EM fields within the tracking area of the radar will vary considerably with the distance to this power line as well as other power distribution and transmission lines. The 76 Hz EM fields that will be generated by the future ELF antenna elements can also be expected to vary considerably over this same area. IITRI Technical Report E06357-16[3] provides the most appropriate approximation of 76 Hz EM field exposures to free-flying migrants with respect to distance from an ELF antenna element. The report was supplied to the principal investigator prior to the onset of the study.

4.2.10 Bird Species and Community Studies

The studies of migratory bird populations employ 20 2.7-mile-long transects, 10 each in the areas of the Wisconsin and Michigan transmitter facilities, and divided evenly between test and control transects. These

4.2.4 Upland Flora and Soil Microflora Studies

A new control site was characterized in 1984. The new test site was needed because of changes in ground terminal number 5 in 1983. Two test sites and one control site remain active. The resulting site pairings are both conditionally acceptable for the following reasons: the control site is near a 69 kV transmission line, the electric and magnetic fields of which fall off rapidly with distance from the line. Because of the large size of the control plot, a gradient of about 10:1 exists in the 60 Hz electric field intensity in earth across the plot, moving in a direction perpendicular to the power line. As a result, the 60 Hz electric field intensities along the side of the plot farthest from the line are lower than the comparable fields at the test sites by more than a factor of ten.

4.2.5 Aquatic Ecosystem Studies

Five new test sites and one new control site were established in 1984, bringing the total number of active sites for this study to ten. One site pairing is acceptable; the others are conditionally acceptable. The primary reason for this categorization is insufficient separation between test and control sites to realize at least a 10:1 ratio in the projected ELF electric field exposure in the earth. However, both the principal investigator and IITRI are cognizant of this, and every effort has been made to maximize the separation while at the same time maintaining the necessary continuity in the aquatic habitat and stream classification. No further site selection is anticipated.

4.2.6 Soil Amoeba Studies

Two new test sites at ground terminal number 4 were characterized in 1984, and one was selected as the study site. One test site and one control site carried over from 1984. The resulting test/control site pairs are both acceptable, and no further site selection is anticipated.

4.2.7 Slime Mold Studies

A new test site adjacent to an overhead antenna element was characterized to replace a marginal site at an underground antenna element. One test site (at a ground) and a control site remain active. Both test/control site pairings are acceptable, and no further site selection is anticipated.

calculated only for site pairings under consideration by the investigators. Tables of the field intensity ratios for each of the ten studies are found in Appendixes A through J.

4.2 STATUS OF SITE SELECTION AND ACCEPTABILITY

Investigators have been given the final decision on the use of study site pairs falling in the acceptable or conditionally acceptable categories, as the effects on the study protocol of both the EM exposure and the biological components need be considered. Unacceptable site pairs, however, do not satisfy the EM exposure protocol and should be relocated or excluded from further study. Based on responses received from the principal investigators through the end of 1984, site selection appears complete for those studies initiated prior to 1984, and an adequate number of acceptable site pairs have been identified for these studies. Bird migration studies begun in 1983 do not employ the paired site concept. Initial transect selection was completed for the study of bird species and communities that was begun late in the 1984 season, but further site selection is required during 1985 to satisfy EM exposure criteria. The following paragraphs summarize the site selection process for each of the ecology studies through the end of 1984.

4.2.1 Small Mammal and Nesting Bird Studies

At the request of the investigator, three new test sites and three new control sites were characterized in 1984. A total of nine sites are still considered active, and all site pairings of interest are either acceptable or conditionally acceptable. No further site selection is anticipated.

4.2.2 Native Bee Studies

One new control site was established in 1984, bringing the total number of active sites to five. All site pairings are acceptable or conditionally acceptable, and no further site selection is anticipated.

4.2.3 Soil Arthropod and Earthworm Studies

Site selection for this study was completed in 1983; however, both sites were remeasured in 1984 to confirm ambient EM exposure levels and study variability.

Unacceptable. A test/control site pair was placed in this category if it neither satisfied the criteria for acceptability nor qualified for conditional acceptability.

TABLE 2. SUMMARY AND STATUS OF TEST/CONTROL SITE PAIRINGS

Study	Number of Needed Test/Control Site Pairs	Number of Potential Test/Control Site Pairs	Number of Sites That Are: Acceptable	Conditionally Acceptable	Unacceptable
Small Mammals and Nesting Birds	2	9	6	3	0
Native Bees	4	6	4	2	0
Soil Arthropods and Earthworms	1	1	1	0	0
Upland Flora and Soil Microflora	2	2	0	2	0
Aquatic Ecosystems	1	9	1	8	0
Soil Amoebae	2	2	2	0	0
Slime Mold	2	2	2	0	0
Wetlands	15	15	14	1	0
Bird Migration	--	--	--	--	--
Bird Species and Communities					
Michigan	25	25	6	4	15
Wisconsin	25	25	12	0	13

The principal investigators for each of the original (pre-1984) studies were given preliminary indications of the acceptability of their new sites at the time of or shortly following the site measurements and documentation in May 1984. Detailed listings of the calculated EM field intensity ratios used to apply the exposure criteria to the paired sites were sent to all investigators during the fourth quarter of 1984. Field intensity ratios were

4. SITE SELECTION RESULTS

4.1 APPLICATION OF ELECTROMAGNETIC EXPOSURE CRITERIA

The EM exposure criteria for site selection discussed in Section 2 were applied to the EM field measurement data for each of the studies. All potentially useful combinations of test and control site pairs within a study were analyzed for acceptability. The results of this exercise are summarized in Table 2. As shown in the table, each site pair was placed in one of three categories: acceptable, conditionally acceptable, or unacceptable.

These categories were defined as follows:

Acceptable. A test/control site pair was placed in this category if it satisfied all four EM exposure inequalities given in Section 2 for each of the EM fields applicable to the study. For example, the small mammal and nesting bird study would be concerned with both the soil and air electric fields as well as the magnetic fields. The soil arthropod and earthworm study, however, would not be concerned with the electric field in air, since this field terminates at the earth's surface and would not be expected to impact biota existing in the soil or litter layer.

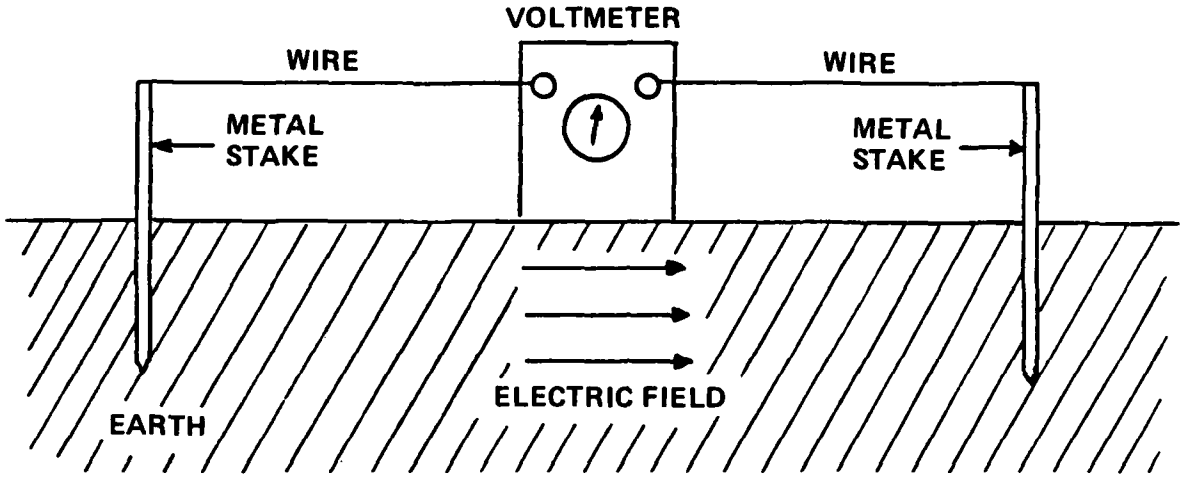
Conditionally Acceptable. A test/control site pair was placed in this category if it approached, but did not meet, the criteria for acceptability. This category was established after recognizing three things. First, the EM exposure criteria were not rigidly defined. The assumption that a difference of one order of magnitude or greater would constitute a significant difference between test and control sites has been chosen for these studies, but without knowing what effects will be experienced, if any. It is difficult to define this difference *a priori*. Second, for the Michigan studies, the 76 Hz field values were estimated for each measurement location. These calculated values were based on a set of estimated electrical parameters (i.e., antenna operating conditions, earth conductivity, and the distance between the measurement location and the planned antenna elements). Some variation can reasonably be expected between the estimated field values and those that will actually be produced when the antenna is built. Third, the EM field measurements themselves encompass a certain degree of error, as do any physical measurements.

system; however, no fields were present within the instrumentation's lowest limits of detection.

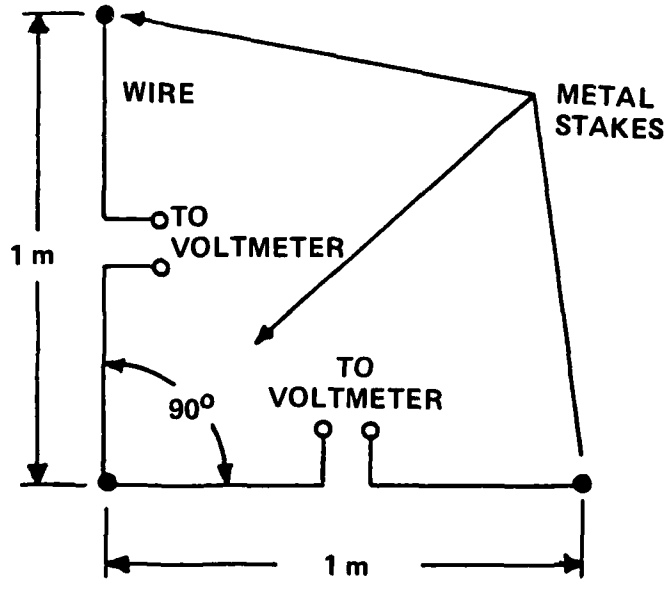
EM field intensity data at a frequency of 60 Hz were recorded for each measurement location selected at the Michigan study sites in a manner similar to that used for the Wisconsin study sites.

In order to evaluate a particular test and control site pair for the Michigan studies, estimates of the 76 Hz EM field intensities were calculated for each measurement location. These estimates were based on calculations utilizing the proposed operating conditions of the Republic transmitter facility antenna elements and the distance from the proposed antenna elements to each measurement location.

Both summarized and detailed listings of the measured 60 and 76 Hz field data for the Wisconsin studies and the measured 60 Hz and estimated 76 Hz field data for the Michigan studies can be found in Appendixes A through J.



a. Measuring a horizontal electric field in the earth.



b. Geometry for perpendicular probe wires.

FIGURE 5. ELECTRIC FIELD IN THE EARTH; MEASUREMENT AND GEOMETRY.

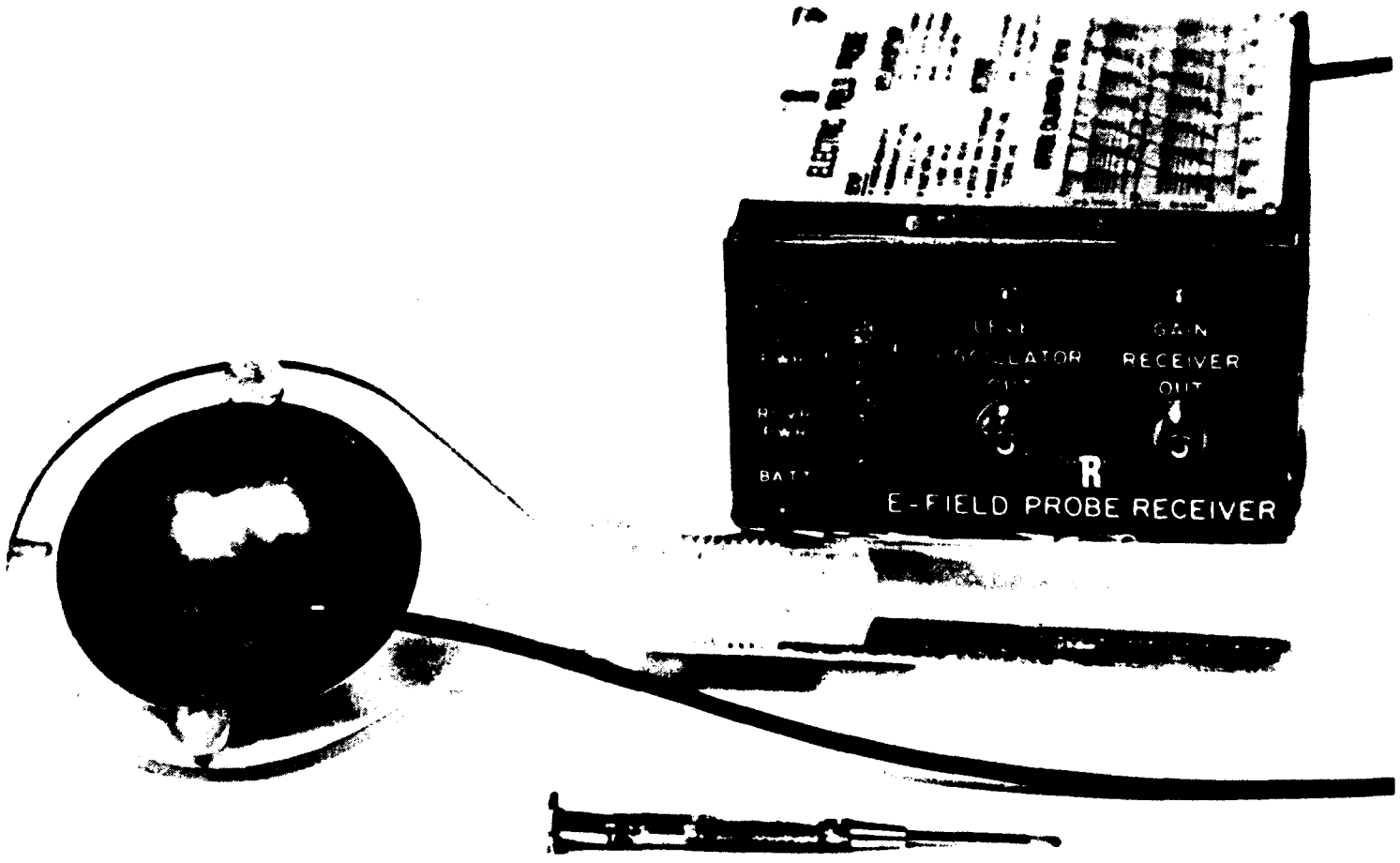


FIGURE 4. ELECTRIC FIELD PROBE.

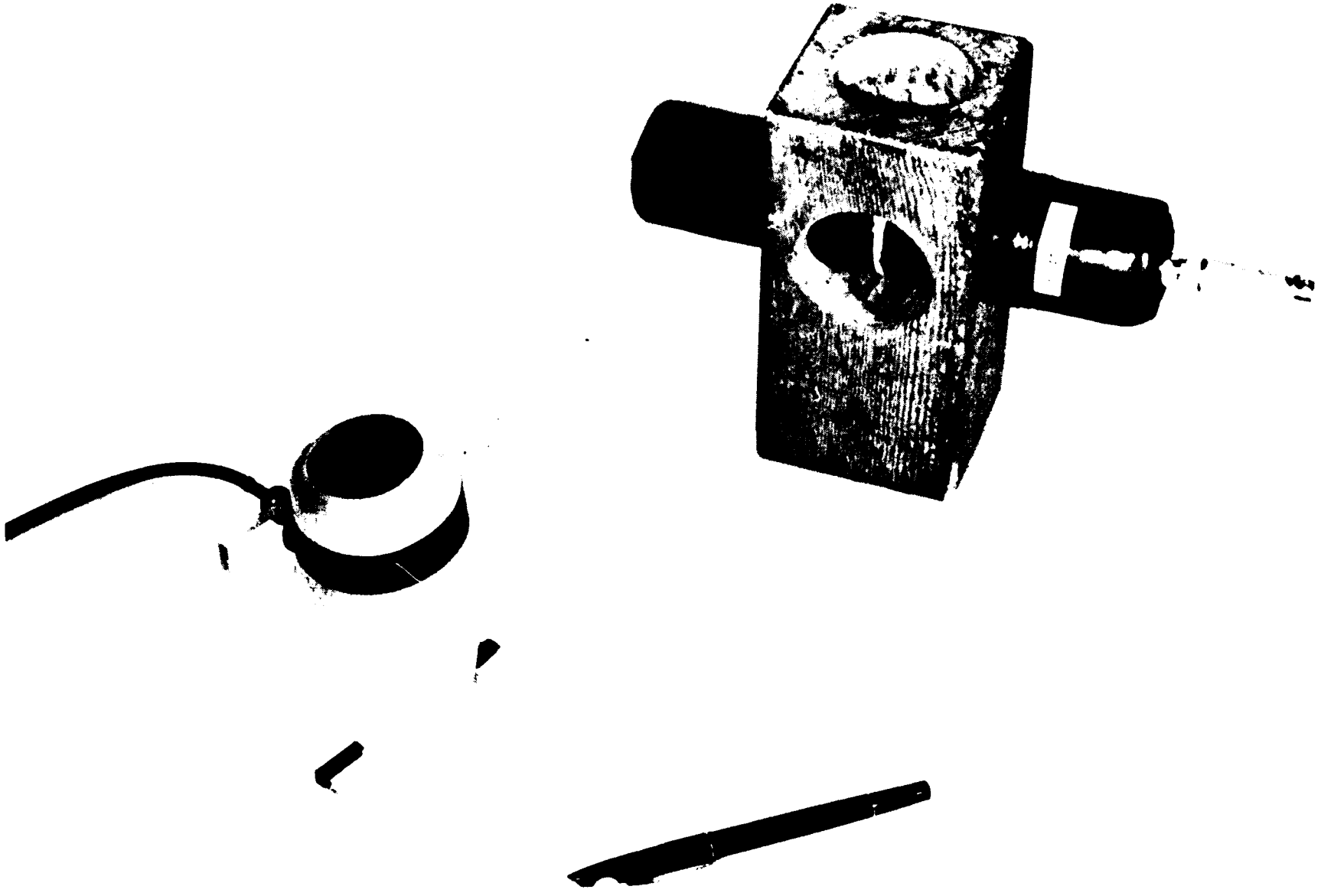


FIGURE 3. MAGNETIC FIELD PROBES.

fields. To identify the presence of any EM field levels at harmonics of 60 Hz (i.e., 120 or 180 Hz), measurement bandwidths of 30 and 300 Hz were also used.

The magnetic flux density was measured using a magnetic field probe composed of multi-turned coils of wire wound on ferrite cores and shunted by appropriately chosen resistors to obtain a flat frequency response. Two of the magnetic field probes are shown in Figure 3.

The electric field intensity in the air was measured using an electric field probe[2] consisting of a spherical sensor/transmitter, an optical fiber data link, and a receiver. The electric field probe is shown in Figure 4.

The electric field intensity in the earth was measured with one-meter probe wires using a methodology and geometry as indicated in Figure 5.

Since the Clam Lake (Wis.) transmitter facility was available for testing while the Republic (Mich.) facility was still in the planning stages, different measurement protocols were used for the Wisconsin and Michigan study sites. In Wisconsin, the three EM fields identified above were measured and transformed as follows:

(1) Orthogonal components of each field were measured with each of the two antenna elements operating one at a time at a continuous frequency of 76 Hz and an antenna current of 150 or 250 amperes. 60 Hz fields were measured with both antenna elements off. This totalled 24 measurements per location.

(2) The orthogonal component measurement data were converted to field levels using the probe calibration factors.

(3) The component field levels at 76 Hz were linearly extrapolated to correspond to a full antenna operating current of 300 amperes (each field is directly proportional to the antenna current).

(4) The field magnitudes for each antenna condition were calculated as the square root of the sum of the squares (RSS) of their orthogonal components.

(5) The "worst case" 76 Hz field magnitudes were computed as the algebraic sum of the magnitudes due to each antenna.

The measurement protocol used for the Michigan study sites did not include the measurement of 76 Hz fields. Attempts were made at several locations in Michigan to measure the ELF fields generated by the Wisconsin

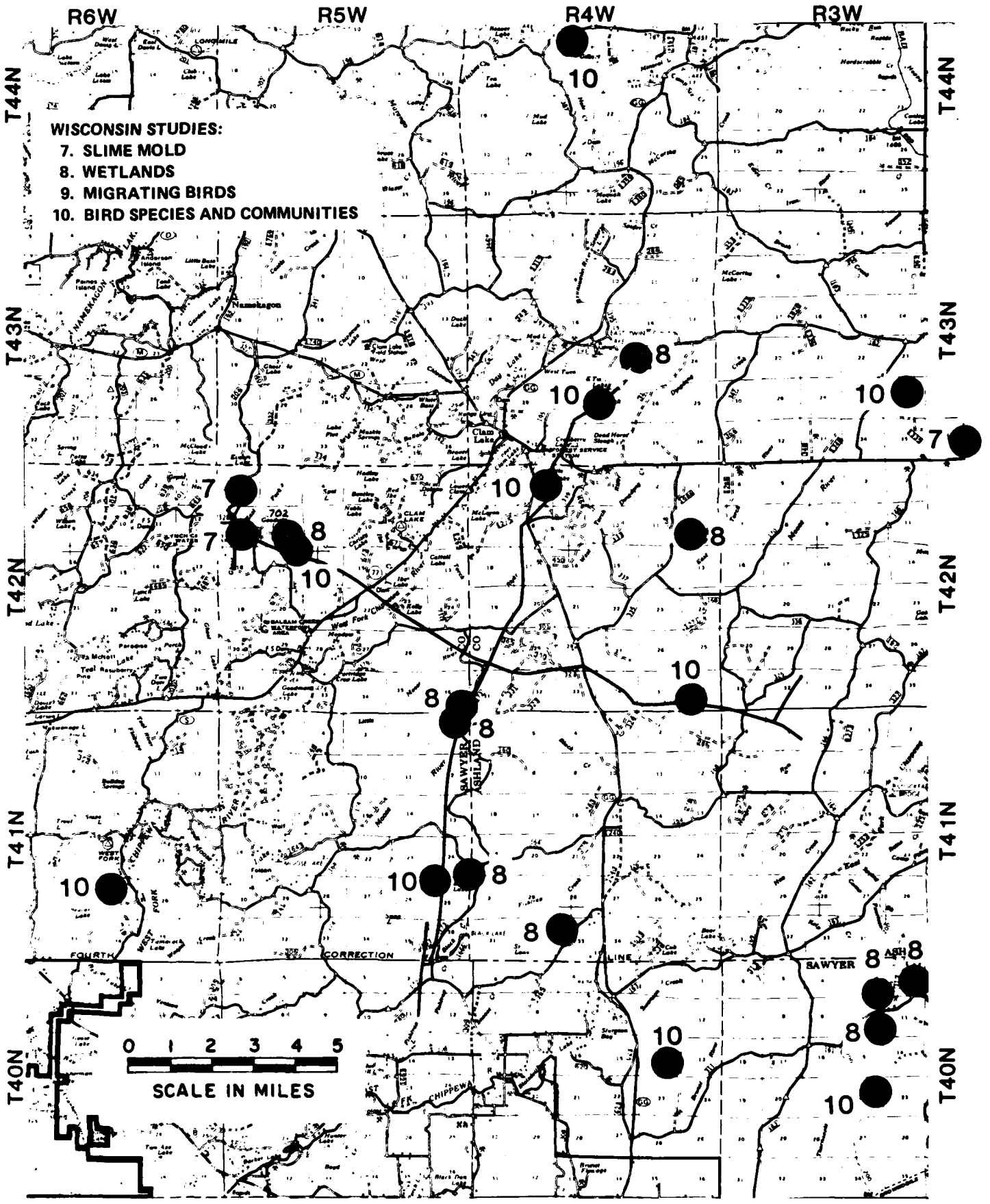


FIGURE 2. FIELD SITES FOR WISCONSIN ECOLOGY STUDIES.

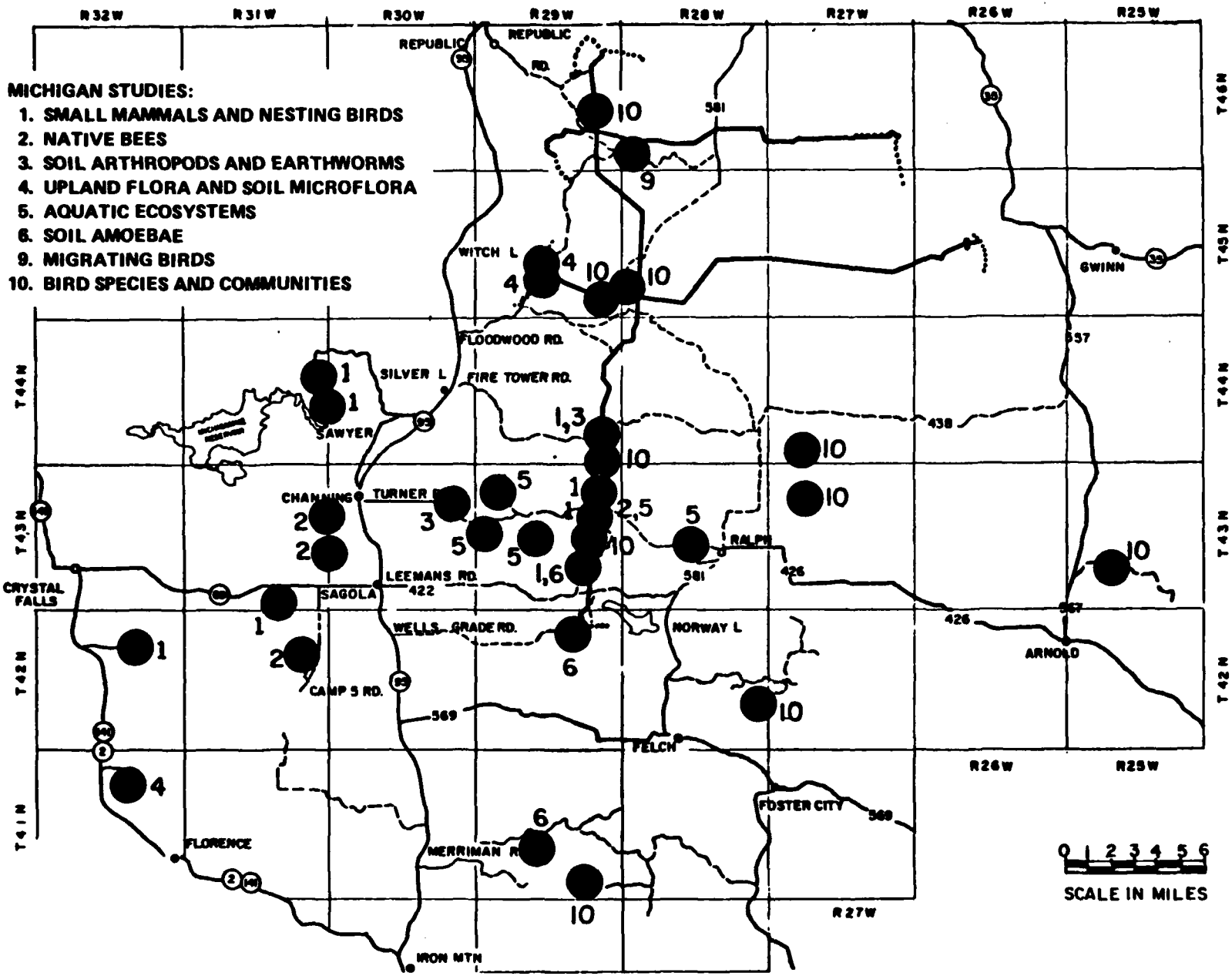


FIGURE 1. FIELD SITES FOR MICHIGAN ECOLOGY STUDIES.

Figures 1 and 2 illustrate the locations of the field sites in use at the end of 1984 relative to transmitter facility antenna elements.

Figure 1 shows the location of field sites for the Michigan studies relative to the planned Republic (Mich.) transmitter facility antenna elements. The eight studies for which EM field measurements were made are identified in the upper left-hand corner of the figure. The black dots represent the locations of field sites at which IITRI field crews evaluated the ELF EM fields.

Similarly, Figure 2 shows the location of field sites for the Wisconsin studies relative to the Clam Lake (Wis.) transmitter facility antenna elements. The four studies for which EM field measurements were made are identified in the upper left-hand corner of the figure. Again, the black dots represent the locations of field sites at which IITRI field crews evaluated the ELF EM fields.

Individual ecology study field site locations are provided in Appendixes A through J.

3.2 MEASUREMENT PROTOCOL

EM field intensity measurements were taken at each measurement location identified. The magnetic flux density and the electric field intensities both in the air and in the earth were measured using directional field probes designed and calibrated by IITRI. Each of these probes, when placed in the existing electric or magnetic field, as appropriate, outputs a voltage proportional to the field intensity. The value of the applied field can be obtained by means of individual sets of laboratory calibration factors for each probe. By taking three orthogonal measurements (two in the case of the electric field intensity in the earth), the magnitude of the electric or magnetic field (vector sum) is derived by calculating the square root of the sum of the squares of the orthogonal components (RSS value).

The meter used to measure the output voltages of the probes was a Hewlett-Packard 3581A Signal Wave Analyzer. The HP 3581A functions as a true rms reading, frequency selective voltmeter, with factory modifications for battery and 1 Hz operation. A measurement bandwidth of 3 Hz was used for single-frequency measurements to discriminate between 60 Hz and 76 Hz

TABLE 1. SUMMARY OF 1984 EM FIELD MEASUREMENT LOCATIONS

Study	Number of Test and Control Sites			Number of Measurement Locations		
	Pre-Existing, Still in Use	New, 1984	Total	Pre-Existing, Still in Use	New, 1984	Total
Small Mammals and Nesting Birds	4	6	10	7	22	29
Native Bees	4	1	5	4	3	7
Soil Arthropods and Earthworms	2	0	2	2	0	2
Upland Flora and Soil Microflora	2	3	5	3	11	14
Aquatic Ecosystems	4	6	10	7	7	14
Soil Amoeba	2	2	4	2	2	4
Slime Mold	3	1	4	3	1	4
Wetlands	9	2	11	0	66	66
Bird Migration	0	1	1	0	1	1
Bird Species and Communities						
Michigan	0	10	10	0	21	21
Wisconsin	0	10	10	0	21	21
TOTAL	30	42	72	28	154	183

sites were documented and measured in the third quarter of 1984. Approximately half of the 50 transect pairings are acceptable or conditionally acceptable, with the remainder unacceptable.

The large number of unacceptable pairings is due primarily to several transects that had one end too close to a power line. The number of acceptable site pairings can be increased significantly by moving the starting points of six transects about one-quarter to one-half mile away from the lines. Three transects, however, cannot be so adjusted and must be relocated. Adjustment and relocation of transects will take place in early spring of 1985.

5. ENGINEERING SUPPORT ACTIVITIES

5.1 SUMMARY OF WISCONSIN TRANSMITTER FACILITY OPERATION

During 1984 as in previous years, the Wisconsin Transmitter Facility (WTF) operated with numerous frequency and modulation conditions in order to accommodate fleet operations, the testing of new hardware, the testing of utility interference mitigation, etc. Wisconsin ecological investigators have requested some type of summary of the modes and hours of operation of the WTF to correlate, if possible, to their studies. To address this need, IITRI personnel have placed the 1984 WTF operating log entries in a computer data base, where they can be manipulated via standard data base or spread sheet software commands.

A summary of WTF operation during 1984 was composed using this data base, and is detailed in Appendix K. Data are presented as hours of operation on a monthly basis for each antenna element, with further delineations for modulated and unmodulated signals of various frequencies. Totals are provided for the hours of operation for each month and signal condition, and for the number of transmitter power-ups.

WTF operation during 1984 can be summarized as follows:

- WTF was transmitting about 55% of the time (about 5000 hours)
- about 85% of "on" time was with a modulated 76 Hz signal
- about 80% of "on" time was accrued in ~12 hr blocks of continuous operation each day
- the remaining 20% of "on" time was in short, intermittent time periods and accounts for most of the transmitter power-ups.

Detailed breakdowns of WTF operation during specific periods are available to investigators as needed.

5.2 CULTURE CELL EM EXPOSURE CONTROL

The soil amoeba and slime mold studies both employ culture cells that isolate the study organisms from the surrounding soil. This in vitro procedure allows close monitoring of biotic endpoints without contamination

from other soil organisms and bacteria, and is necessary for a controlled study. The soil amoeba culture cell consists of an inverted T-shape plastic tube about 15 cm long and 2 cm in diameter. Stainless steel disk electrodes mounted on silicone rubber stoppers are inserted in each end to contain the saline solution growth medium and provide EM exposure. The slime molds are grown on 1-cm-thick agar contained in a covered plastic tray approximately 9 cm by 16 cm. Stainless steel rod electrodes embedded in the agar at each end provide EM exposure. The culture cells and electrodes are shown in Figures 6 and 7.

Both culture cells are buried in the earth at shallow depths at test and control sites, thus exposing the cultures of soil amoebae and slime mold to the earth's ambient temperature and its variations. It is also desirable to expose the cultures to the same EM environment that they would encounter if living in the soil or litter layer, rather than in or on a culture medium. Ideally, this would be accomplished by simply connecting the culture cell electrodes directly to the earth where they were buried, so that the electric voltages and currents present in the earth could be applied to and flow through the culture medium in the cell. In reality, however, EM exposure in the culture cells is complicated by a mismatch between the conductivities of the soil and those of the culture media. Laboratory experiments were conducted to determine the conductivities of various soil layers and those of the culture media of interest. The results are presented in Table 3. As shown in the table, the culture media conductivities exceed those of the soil by a factor of at least 100. This means that a culture cell directly connected to the earth would have a lower electric field and a higher current density than in the surrounding soil. The differences in conductivity also mean that the electric field and current density in the culture cells cannot both be matched to the soil conditions at the same time.

External control circuitry must therefore be used to regulate the drive voltages and currents supplied to the culture cells from a set of collector electrodes in the earth. Calculations were made of the culture cell drive voltages and currents required to provide matched electric field or current density exposure protocols as a function of the unperturbed electric field in the earth. The results are given in Tables 4 and 5, and are normalized to a 1 V/m earth electric field.

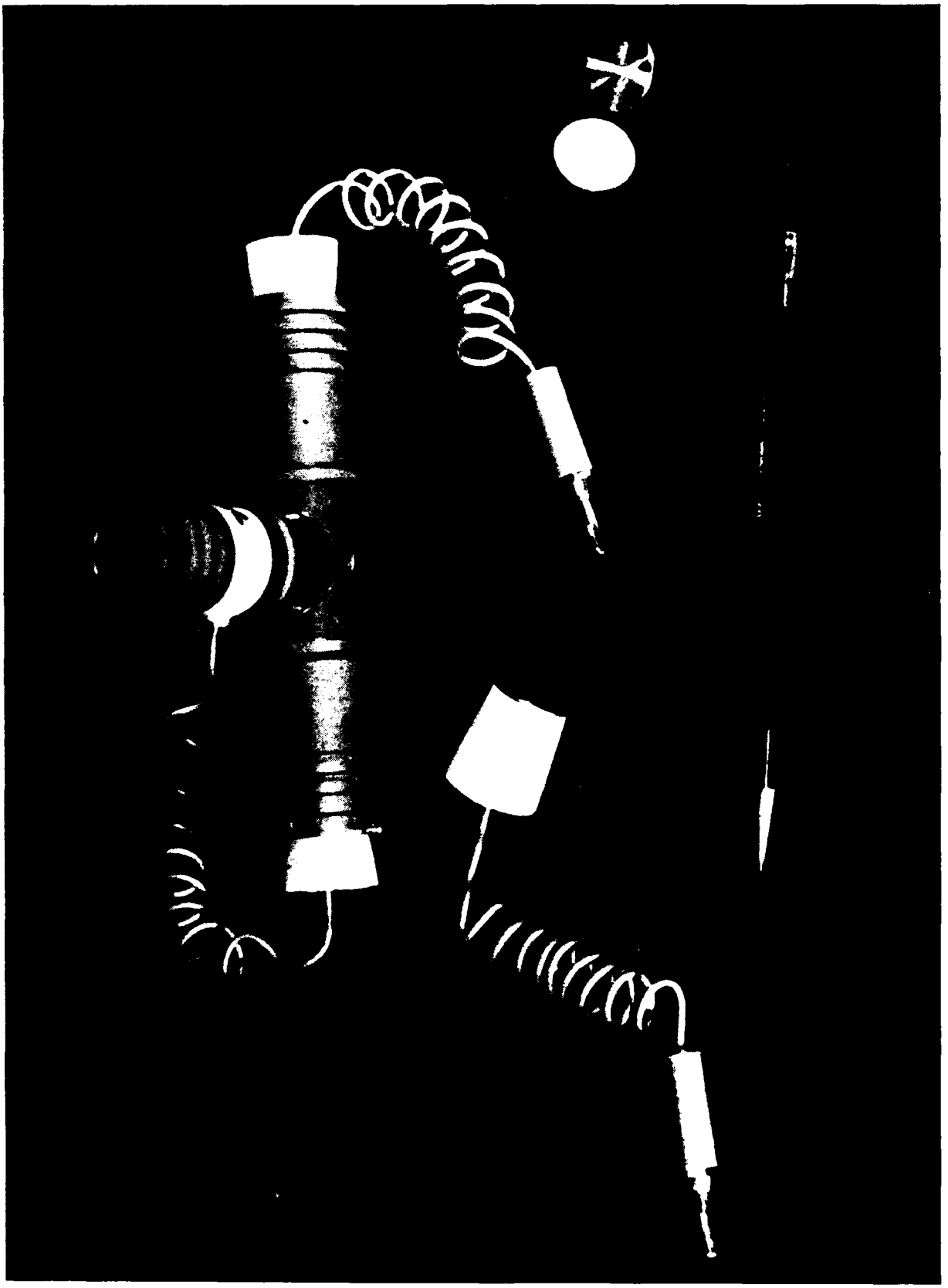


FIGURE 6. SOIL AMOEBA CULTURE CELL AND ELECTRODES.

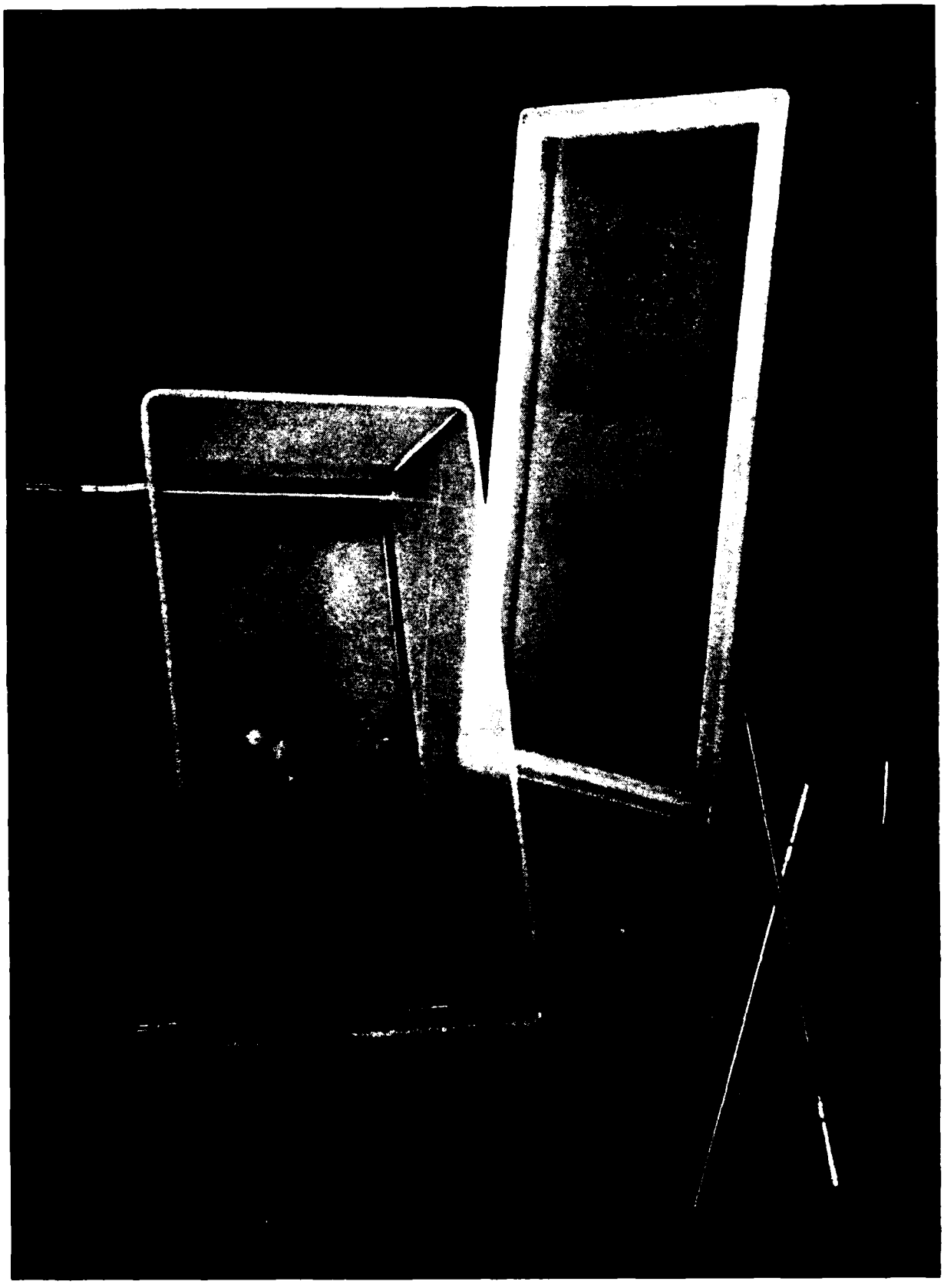


FIGURE 7. SLIME MOLD CULTURE CELL AND ELECTRODES.

TABLE 3. ELECTRICAL PROPERTIES OF SOIL LAYERS AND CULTURE MEDIA AT 76 HZ

Medium	Measured Bulk Conductivity, mhos/m	Current Density, A/m^2 (Normalized to E = 1 V/m)
Soil Upper Layer	0.0033-0.0046	0.0033-0.0046
Soil Lower Layer	0.0015-0.0016	0.0015-0.0016
Saline Solution	0.44-0.56	0.44-0.56
Agar	0.22-0.27	0.22-0.27

TABLE 4. TEST CELL VOLTAGE REQUIRED FOR MATCHED E-FIELD PROTOCOL*

Study	Test Cell Voltage, V
Soil Amoebae	0.113
Slime Mold	0.155

*Normalized to E = 1 V/m

TABLE 5. TEST CELL CURRENT REQUIRED FOR MATCHED CURRENT DENSITY PROTOCOL*

	Test Cell Current to Match		
Study	Upper Soil Layer, μA	Lower Soil Layer, μA	Average, μA
Soil Amoebae	0.46-0.65	0.21	~0.4
Slime Mold	2.0-4.1	1.3	~2.0

*Normalized to E = 1 V/m

Field measurements were conducted at the slime mold study sites, using the collector electrodes in place at these locations, to determine the 76 Hz voltages and currents that could be sourced by the electric field in earth as a function of load impedance. The test setup is illustrated in Figure 8. An equivalent circuit of the earth source voltage test setup equivalent circuit is shown in Figure 9. The results of the test are presented in Figure 10. The curves shown in the figure are normalized to a 1 V/m open-circuit,

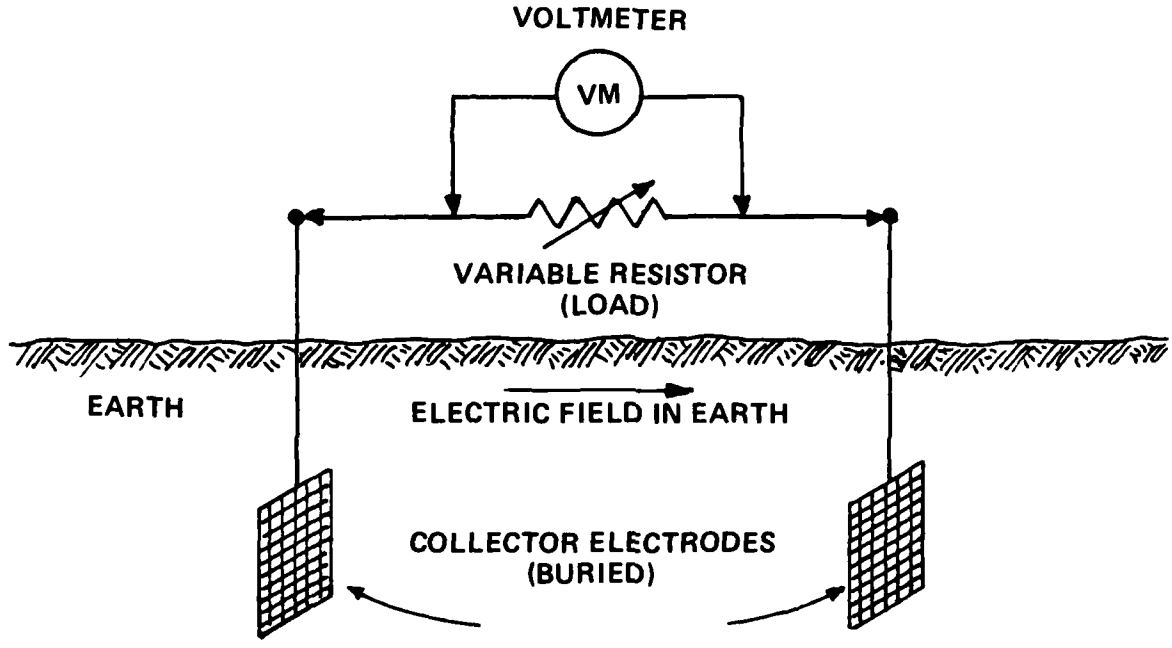


FIGURE 8. EARTH SOURCE VOLTAGE AND CURRENT TEST SETUP.

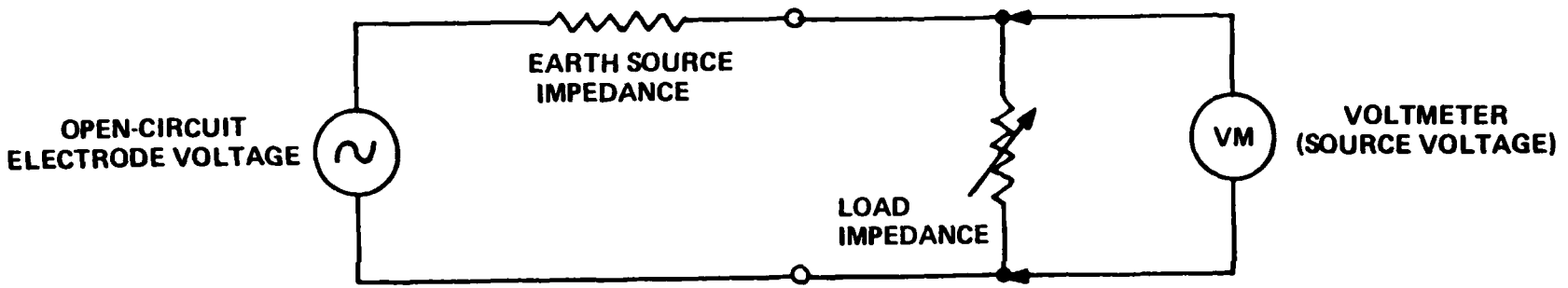


FIGURE 9. EQUIVALENT CIRCUIT OF EARTH SOURCE VOLTAGE.

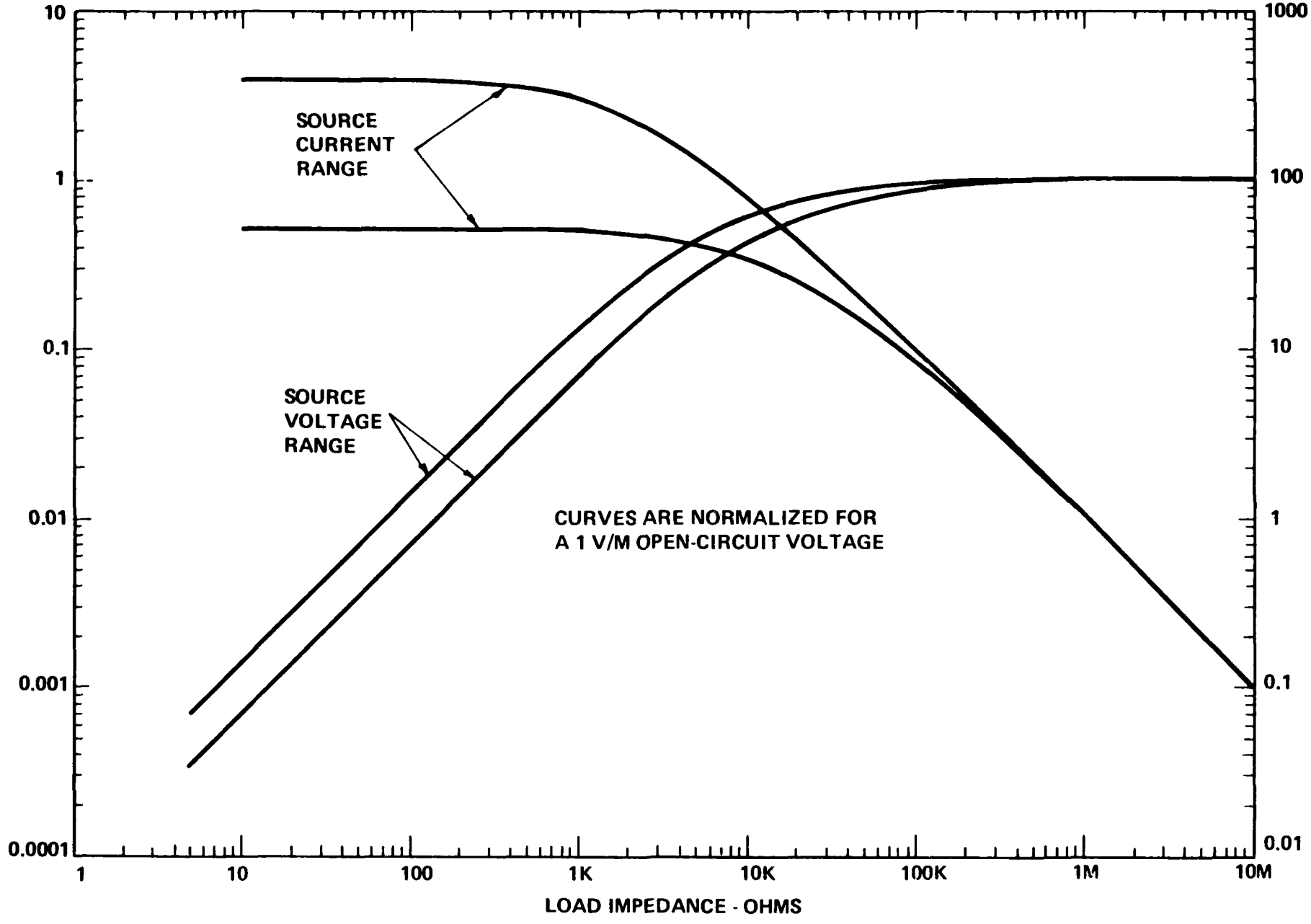


FIGURE 10. EARTH SOURCE VOLTAGE AND CURRENT AS FUNCTION OF LOAD IMPEDANCE.

collector-electrode voltage. The variability in the source voltages and currents for low values of load impedance reflect similar variations in the soil conductivity, and thus in effective source impedance, from site to site. Source impedances ranged from 4 kΩ to 16 kΩ.

Culture cells represent low impedance loads because of their high conductivity culture media. Thus, culture cell EM exposure will also vary considerably from site to site with the earth source impedance if left unregulated. This variability can be corrected for, however, with properly designed and adjusted control circuitry.

Two basic culture cell drive control circuits were developed: one for matching E-field exposure and one for matching current density exposure between the cells and the earth. These circuits are illustrated in Figures 11 and 12. The electric field exposure circuit of Figure 11 uses a low value variable resistor to adjust the voltage across the culture cell to the desired value. A fixed value resistor allows the cell current to be determined by measuring the voltage across the resistor element and dividing this voltage by the value of the resistance. The current density exposure circuit of Figure 12 uses large valve fixed resistors to set the cell current. A switch allows either a matched current density exposure, or an exposure about midway between matched electric field and matched current density.

Exposure setup protocols were developed for both the soil amoeba and slime mold studies to aid investigators in setting up, adjusting, and monitoring the EM exposures in the culture cells. These protocols were tailored for each of the studies, and are presented in Appendix L.

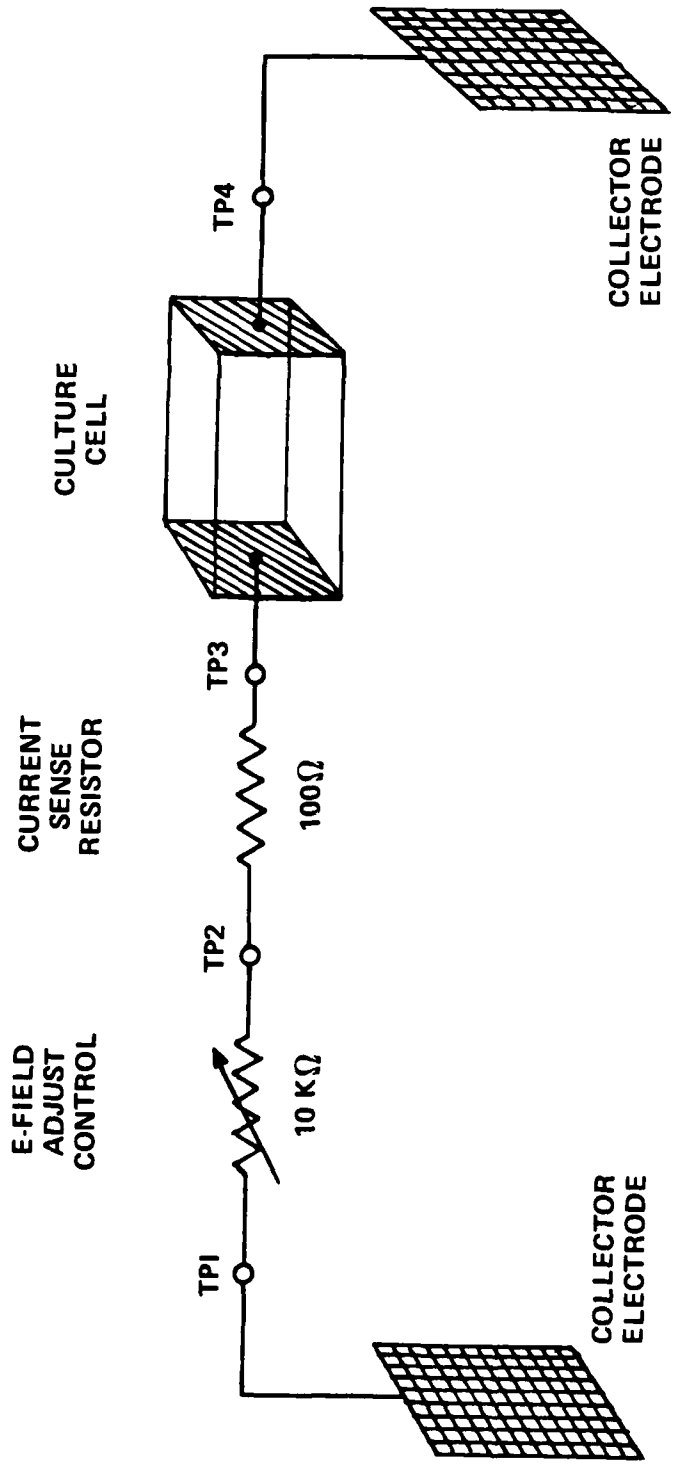


FIGURE 11. DRIVE/CONTROL CIRCUIT FOR MATCHED E-FIELD EXPOSURE.

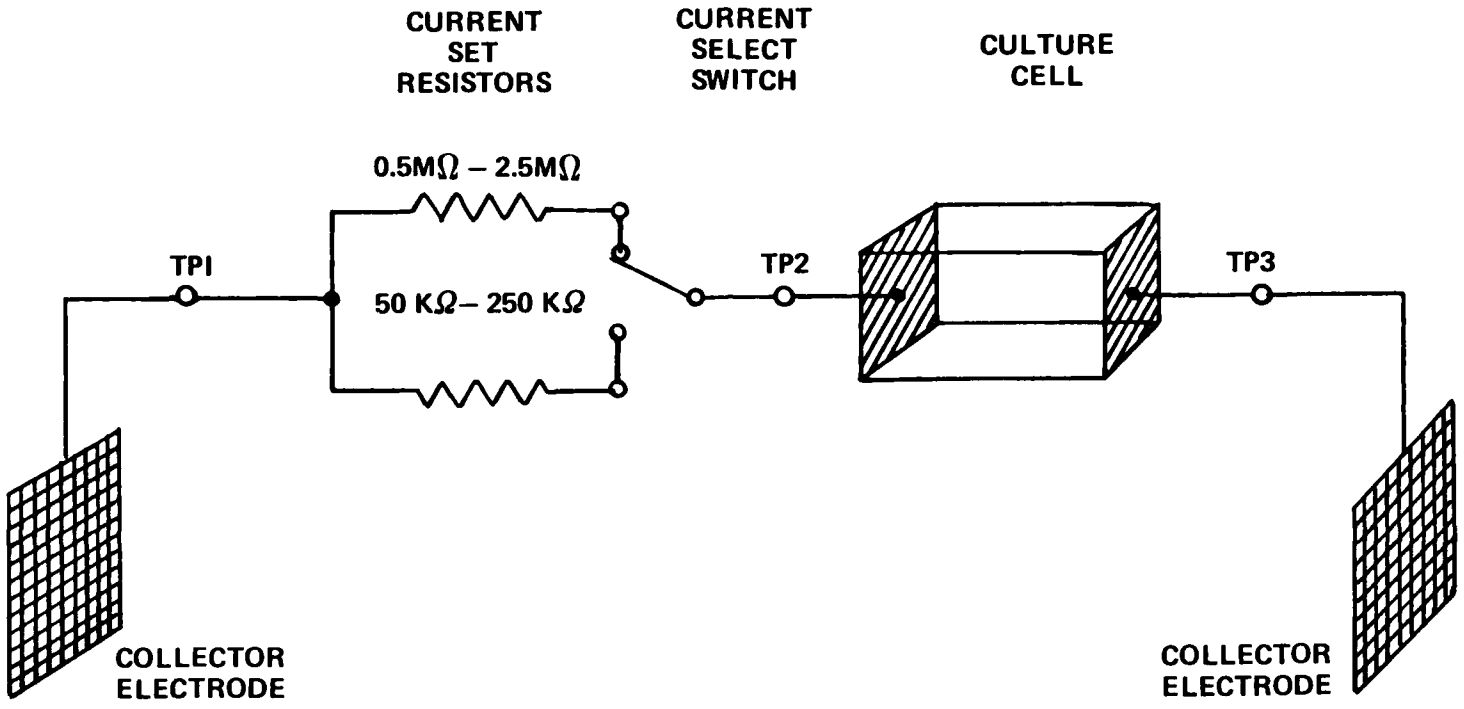


FIGURE 12. DRIVE/CONTROL CIRCUIT FOR MATCHED CURRENT DENSITY EXPOSURE.

PREVIOUS PAGE IS BLANK

6. CONCLUSIONS

During 1984, the ELF EM fields at 42 new ecological study sites were characterized for the first time, and 30 existing sites were remeasured to study year-to-year variability. A total of 183 measurement sets were taken. All potential study sites that were identified by investigators during the 1984 field season were visited by IITRI field crews, ELF EM field measurements were made, and the results were documented.

The principal investigators for all of the ecological studies were provided with details of the measurement site locations, summaries of the measured electromagnetic fields, and analyses of the EM exposure acceptability of each of their test/control site pairings.

Engineering support was provided for the soil amoeba and slime mold studies to assure proper EM exposure in the culture cells used for the *in vitro* portions of these investigations. Laboratory measurements were made to determine the conductivity of various soil layers and culture growth media. Field measurements were made to determine earth source voltages, currents, and impedances at typical study sites. Drive circuitry was then designed and prototyped to control the electric field or current density in culture cells deployed in the field. Test protocols were developed to aid the study investigators in setting up and adjusting the EM exposure control apparatus.

In summary, only one study, that of bird species and communities which was begun late in the 1984 season, should require further site selection and EM characterization efforts. These additional EM field measurements are scheduled for early spring 1985 so as to provide the investigators of this study with an entire field season for baseline data acquisition. Also scheduled for that time are the fabrication and setup of EM exposure control apparatus for the soil amoeba and slime mold studies, which will require further engineering guidance.

Annual remeasurement and verification of the ELF EM fields at all active ecological test and control sites is scheduled for the third quarter of 1985. As in past years, specific engineering support will be provided to the study investigators as needed.

7. REFERENCES

1. ELF Communications System Ecological Monitoring Program: Measurements of ELF Electromagnetic Fields for Site Selection and Characterization--1983. IIT Research Institute Technical Report E06549-10, January 1985. J. O. Enk and J. R. Gauger. Available from National Technical Information Service (NTIS), Springfield, Va.

2. An Improved ELF Electric Field Probe. IIT Research Institute Technical Memorandum No. 2, IITRI Project No. E6249, March 1974. V. C. Formanek. Available from NTIS.

3. Electric and Magnetic Field Calculations in Support of Bird Migration Studies at the Wisconsin Test Facility. IIT Research Institute Technical Report E06357-16, July 1978. D. Lanera. Available from NTIS.

PREVIOUS PAGE IS BLANK

TABLE B-4. FIELD RATIOS' MAGNITUDE[1]
Native Bee Studies

Compared Site Nos.	Transverse E Field (Air)				Longitudinal E Field (Earth)				Magnetic Flux Density			
	R1	R2	R3	R4	R1	R2	R3	R4	R1	R2	R3	R4
2T1/2C2	130000	130000	8130	*0.06	84	320	28.5	*0.09	600	15000	2307	0.15
2T1/2C4	130000	130000	130000	1.00	84	320	525.0	1.63-2.60	600	15000	7500	0.50-0.67
2T1/2C5	130000	130000	130000	1.00	84	320	90.3	0.28-2.00	10000	15000	150000	1.00-2.00
2T2/2C2	130000	130000	8130	*0.06	84	106	28.5	0.27	600	30000	2307	*0.077
2T2/2C4	130000	130000	130000	1.00	84	106	525.0	4.93-7.90	600	30000	7500	0.25-0.33
2T2/2C5	130000	130000	130000	1.00	84	106	90.3	0.85-6.08	10000	30000	15000	0.50-1.00

[1] $R_1 = \frac{T(76\ Hz)}{C(76\ Hz)}$, $R_1 \geq 10$

$R_2 = \frac{T(76\ Hz)}{T(60)}$, $R_2 \geq 10$

$R_3 = \frac{T(76\ Hz)}{C(60)}$, $R_3 \geq 10$

$R_4 = \frac{T(60)}{C(60)}$, $0.1 \leq R_4 \leq 10$.

When a range of values were available for calculating a given ratio, the ratio range was calculated as follows:

High Limit ---> Maximum Numerator Value/Minimum Denominator Value
Low Limit ---> Minimum Numerator Value/Maximum Denominator Value

* Does not meet the exposure criteria.

TABLE B-3. ELECTRIC FIELD INTENSITIES AND MAGNETIC FLUX DENSITIES[1,2]
Native Bee Studies

Site No.	Meas. Pt.	Meas. Yr.	Transverse E Field (Air), V/M		Longitudinal E Field (Earth), mV/M		Magnetic Flux Density, mG	
			76 Hz	60 Hz	76 Hz	60 Hz	76 Hz	60 Hz
2C2	1	1983	<0.001	0.019	1.0	1.80	<0.05	0.007
2C2	1	1984	<0.001	0.016	1.0	2.95	<0.05	0.013
2C4	1	1983	<0.001	<0.001	1.0	0.011	<0.05	0.004
2C4	1	1984	<0.001	<0.001	1.0	0.16	<0.05	0.004
2C4	1	1984	<0.001	--	1.0	0.10	<0.05	0.003
2C4	1	1984	<0.001	--	1.0	0.14	<0.05	0.003
2C5	1	1984	<0.001	<0.001	1.0	0.64	0.003	0.001
2C5	1	1984	<0.001	--	1.0	0.90	0.003	0.002
2C5	1	1984	<0.001	--	1.0	0.93	0.003	0.002
2C5	2	1984	<0.001	<0.001	1.0	0.23	0.003	<0.001
2C5	3	1984	<0.001	<0.001	1.0	0.13	0.003	0.001
2T1	1	1983	130	0.004	84.0	0.23	30.0	0.001
2T1	1	1984	130	<0.001	84.0	0.26	30.0	0.002
2T2	1	1983	130	<0.001	84.0	0.071	30.0	0.002
2T2	1	1984	130	<0.001	84.0	0.74	30.0	0.001
2T2	1	1984	130	<0.001	84.0	0.88	30.0	0.001
2T2	1	1984	130	0.001	84.0	0.80	30.0	0.001
2T2	1	1984	130	<0.001	84.0	0.65	30.0	0.001
2T2	1	1984	130	<0.001	84.0	0.88	30.0	0.001

[1] Data listed for 76 Hz is estimated based on analysis using the proposed location and operating conditions of the antenna elements along with the distance to each measurement point.

[2] Values shown are magnitudes determined as the square root of the sum of the square of the orthogonal field components.

TABLE B-2. POTENTIAL SITE PAIRINGS AND ACCEPTABILITY

Test Site	Control Site	Site Pair Acceptability
2T1	2C2	Conditionally Acceptable
	2C4	Acceptable
	2C5	Acceptable
2T2	2C2	Conditionally Acceptable
	2C4	Acceptable
	2C5	Acceptable

Data listed for the magnitudes of the fields produced by the ELF system were estimated at a frequency of 76 Hz (the expected operating frequency) and based on calculations utilizing the proposed location and operating conditions of the Republic Transmitter Facility antenna elements and the distance to each measurement point. Table B-3 presents a summary of the measured and estimated data for 1984 taken at each of the currently active sites. Where applicable, 1983 data are also presented for reference.

The ELF EM field exposure criteria were applied to the data by computing the field intensity ratios utilized in the mathematical representation of the exposure criteria (see Section 2.1). The results of this effort are illustrated in Table B-4.

The investigator has acceptable control test pairings for his studies that meet electromagnetic criteria.

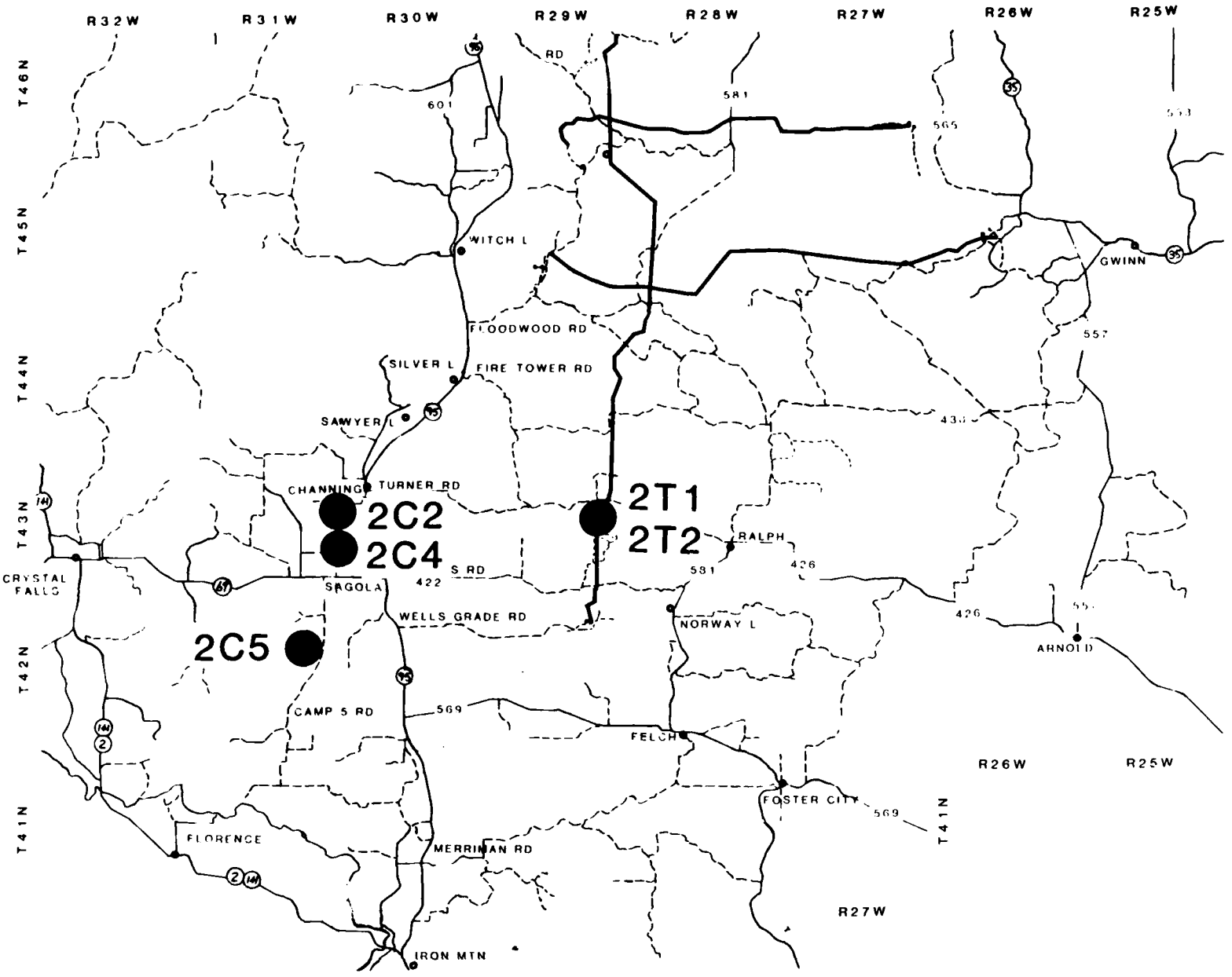


FIGURE B-1. POSITIONS OF TEST AND CONTROL SITES RELATIVE TO TRANSMITTER FACILITY ANTENNA ELEMENTS.

NATIVE BEE STUDIES

On 16 May 1984 and on 13 through 16 August, 20 August, and 22 August 1984, IITRI field crews made ELF EM field measurements at seven measurement points on a total of five test and control sites for native bee studies. The five sites included four sites previously measured and still in use plus one new site: 2C5. The positions of these five sites relative to the proposed Republic Transmitter Facility antenna elements are shown on the composite map in Figure B-1. The site numbers listed on the map are those used by IITRI. Table B-1 provides a cross-reference of IITRI site numbers, investigator site names, and township, range, and section numbers for the sites.

TABLE B-1. SITE NO. CROSS-REFERENCE

IITRI Site No.	Investigator's Site Name	Location		
		Township	Range	Section(s)
2T1	Ford River North--Test	T43N	R29W	14
2T2	Ford River South--Test	T43N	R29W	14
2C2	Channing Control 2	T43N	R30W	18
2C4	County Line Road Control	T43N	R30W	19
2C5	Camp 5 Control	T42N	R31W	13

The native bee study incorporates studies of both nesting and development traits. The electric and magnetic fields present in the air are considered the most important factors in the orientation and site tenacity of bees during their nesting cycle. The electric and magnetic fields in the earth near the surface may be of importance in developmental studies.

Table B-2 shows the site pairings of interest to the investigator and the acceptability of each pair as defined in Section 4.1.

PREVIOUS PAGE IS BLANK

APPENDIX B

NATIVE BEE STUDIES

TABLE A-4. FIELD RATIOS' MAGNITUDE[1]
Small Mammal and Nesting Bird Studies

Compared Site Nos.	Transverse E Field (Air)				Longitudinal E Field (Earth)				Magnetic Flux Density			
	R1	R2	R3	R4	R1	R2	R3	R4	R1	R2	R3	R4
1T1/1C1	>100	>100	>100	1	>37	>262	>367	0.12-1.90	>100	>375	>1500	2.0-4.00
1T1/1C3	>100	>100	>100	1	>37	>262	>212	*0.07-1.11	>100	>375	>500	0.68-2.00
1T1/1C4	>100	>100	>100	1	>55	>262	>846	0.28-11.05*	>100	>375	>750	1.00-4.00
1T1/1C6	>100	>100	>100	1	>55	>262	>611	0.20-3.00	>150	>375	>500	0.67-1.33
1T2/1C4	>100	>100	>100	1	>55	>250	>846	3.39-11.58*	>100	>1500	>750	0.50-1.00
1T2/1C6	>100	>100	>100	1	>55	>250	>611	2.44-3.14	>150	>1500	>500	0.33
1T4/1C6	>100	>100	>100	1	>55	>204	>611	1.89-3.86	>150	>1500	>500	0.33
1T5/1C6	>100	>100	>100	1	>55	>131	>611	2.67-6.00	>150	>750	>500	0.33-0.68
1T6/1C6	>100	>100	>100	1	>55	> 63	>611	7.22-12.58*	>150	>1500	>500	0.33

[1] $R_1 = \frac{T(76\ Hz)}{C(76\ Hz)}$, $R_1 \geq 10$

$R_2 = \frac{T(76\ Hz)}{T(60)}$, $R_2 \geq 10$

$R_3 = \frac{T(76\ Hz)}{C(60)}$, $R_3 \geq 10$

$R_4 = \frac{T(60)}{C(60)}$, $0.1 \leq R_4 \leq 10$.

When a range of values were available for calculating a given ratio, the ratio range was calculated as follows:

High Limit ---> Maximum Numerator Value/Minimum Denominator Value
Low Limit ---> Minimum Numerator Value/Maximum Denominator Value

* Does not meet the exposure criteria.

TABLE A-3. ELECTRIC FIELD INTENSITIES AND MAGNETIC FLUX DENSITIES[1,2]
Small Mammal and Nesting Bird Studies (Page 2 of 2)

Site No.	Meas. Pt.	Meas. Yr.	Transverse E Field (Air), V/M		Longitudinal E Field (Earth), mV/M		Magnetic Flux Density, mG	
			76 Hz	60 Hz	76 Hz	60 Hz	76 Hz	60 Hz
1T1	11	1984	0.1-150	<0.001	55-80	0.050	1.5-30	0.003
1T2	1	1983	0.1-150	<0.001	55-80	0.17	1.5-30	<0.001
1T2	1	1984	0.1-150	<0.001	55-80	0.22	1.5-30	<0.001
1T2	2	1983	0.1-150	<0.001	55-80	0.15	1.5-30	<0.001
1T4	1	1984	0.1-150	--	55-80	0.17	1.5-30	<0.001
1T4	1	1984	0.1-150	<0.001	55-80	0.18	1.5-30	<0.001
1T4	2	1984	0.1-150	--	55-80	0.22	1.5-30	<0.001
1T4	2	1984	0.1-150	<0.001	55-80	0.27	1.5-30	<0.001
1T5	1	1984	0.1-150	--	55-80	0.24	1.5-30	0.001
1T5	1	1984	0.1-150	<0.001	55-80	0.42	1.5-30	0.002
1T5	2	1983	0.1-150	<0.001	55-80	0.23	1.5-30	0.001
1T5	2	1984	0.1-150	<0.001	55-80	0.26	1.5-30	0.002
1T6	1	1983	0.1-150	<0.001	55-80	0.071	1.5-30	0.002
1T6	1	1984	0.1-150	<0.001	55-80	0.88	1.5-30	0.001
1T6	1	1984	0.1-150	<0.001	55-80	0.65	1.5-30	0.001
1T6	1	1984	0.1-150	<0.001	55-80	0.80	1.5-30	0.001
1T6	1	1984	0.1-150	<0.001	55-80	0.88	1.5-30	0.001
1T6	1	1984	0.1-150	<0.001	55-80	0.74	1.5-30	0.001

[1] Data listed for 76 Hz is estimated based on analysis using the proposed location and operating conditions of the antenna elements along with the distance to each measurement point.

[2] Values shown are magnitudes determined as the square root of the sum of the square of the orthogonal field components.

TABLE A-3. ELECTRIC FIELD INTENSITIES AND MAGNETIC FLUX DENSITIES[1,2]
Small Mammal and Nesting Bird Studies (Page 1 of 2)

Site No.	Meas. Pt.	Meas. Yr.	Transverse E Field (Air), V/M		Longitudinal E Field (Earth), mV/M		Magnetic Flux Density, mG	
			76 Hz	60 Hz	76 Hz	60 Hz	76 Hz	60 Hz
1C1	1	1983	<0.001	<0.001	1.5	0.059	0.015	<0.001
1C1	1	1984	<0.001	<0.001	1.5	0.11	0.015	0.001
1C1	2	1983	<0.001	--	1.5	0.041	0.015	<0.001
1C1	2	1984	<0.001	--	1.5	0.15	0.015	0.001
1C3	1	1983	<0.001	--	<1.0	0.11	0.015	<0.001
1C3	1	1984	<0.001	--	<1.0	0.26	0.015	0.002
1C3	2	1983	<0.001	--	<1.0	0.13	0.015	0.001
1C3	2	1984	<0.001	--	<1.0	0.19	0.015	0.003
1C4	1	1984	<0.001	--	<1.0	0.028	0.015	<0.001
1C4	1	1984	<0.001	0.001	<1.0	0.030	0.015	0.001
1C4	2	1984	<0.001	--	<1.0	0.019	0.015	0.002
1C4	2	1984	<0.001	<0.001	<1.0	0.023	0.015	0.002
1C4	3	1984	<0.001	--	<1.0	0.065	0.015	<0.001
1C4	3	1984	<0.001	--	<1.0	0.036	0.015	0.002
1C6	1	1984	<0.001	0.001	<1.0	0.070	0.010	0.003
1C6	2	1984	<0.001	0.001	<1.0	0.092	0.010	0.003
1T1	1	1983	0.1-150	<0.001	55-80	0.090	1.5-30	0.002
1T1	1	1984	0.1-150	--	55-80	0.091	1.5-30	0.002
1T1	2	1983	0.1-150	<0.001	55-80	0.021	1.5-30	0.002
1T1	2	1984	0.1-150	<0.001	55-80	0.018	1.5-30	0.002
1T1	3	1984	0.5-1	--	55	0.21	3	0.002
1T1	4	1984	0.5-1	--	55	0.18	3	0.002
1T1	5	1984	0.1-150	--	55-80	0.090	1.5-30	0.002
1T1	6	1984	0.1-150	--	55-80	0.13	1.5-30	0.002
1T1	7	1983	0.1-150	<0.001	55-80	0.087	1.5-30	0.001
1T1	7	1984	0.1-150	--	55-80	0.11	1.5-30	0.002
1T1	8	1984	0.1-150	--	55-80	0.090	1.5-30	0.003
1T1	9	1984	0.1-150	--	55-80	0.14	1.5-30	0.004
1T1	10	1984	0.1-150	--	55-80	0.10	1.5-30	0.004

of the Republic Transmitter Facility antenna elements and the distance to each measurement point. Table A-3 presents a summary of the measured 60 Hz and estimated 76 Hz data for 1984 taken at measurement points for each of the currently active sites. Where applicable, 1983 data are also presented for reference.

The ELF electromagnetic field exposure criteria were applied to the data by computing the field intensity ratios utilized in the mathematical representation of the exposure criteria (see Section 2.1). The results of this effort are illustrated in Table A-4.

The investigator has acceptable test/control pairings for each of his studies that meet electromagnetic exposure criteria.

The objectives of the small mammal and nesting bird studies consist of parental care, nestling growth and maturation, fecundity, homing, activity patterns, embryological development, and metabolic physiology. The electric and magnetic fields in the air are considered important factors to be examined in orientation and other behavior patterns. The electric and magnetic fields in the earth near the surface may be important to other objectives of this study.

Table A-2 shows the site pairings of interest to the investigator and the acceptability of each pair as defined in Section 4.1.

TABLE A-2. POTENTIAL SITE PAIRINGS AND ACCEPTABILITY

Test Site	Control Site	Site Pair Acceptability
1T1	1C1	Acceptable
	1C3	Conditionally Acceptable
	1C4	Conditionally Acceptable
	1C6	Acceptable
1T2	1C4	Conditionally Acceptable
	1C6	Acceptable
1T4	1C6	Acceptable
1T5	1C6	Acceptable
1T6	1C6	Acceptable

Site pairs that include test site 1T1 are to be used for studies of parental care, homing, activity patterns, and census; pairs that include test site 1T2 are to be used for studies of embryology, homing, parental care, and growth; pairs that include test sites 1T5 or 1T6 are to be used for studies of embryology and homing.

Data listed for the magnitudes of the fields produced by the ELF system were estimated at a frequency of 76 Hz (the expected operating frequency) and based on calculations utilizing the proposed location and operating conditions

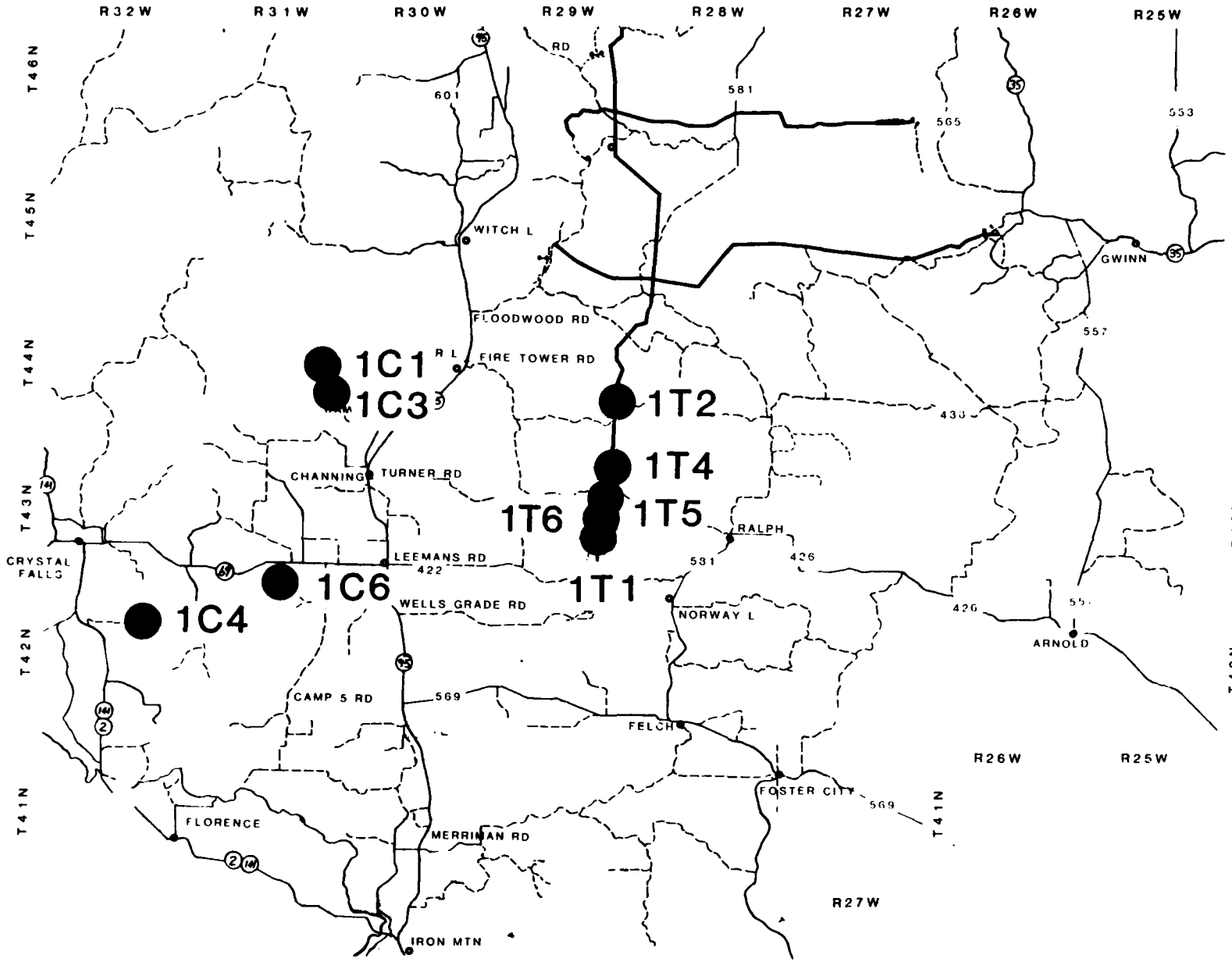


FIGURE A-1. POSITIONS OF TEST AND CONTROL SITES RELATIVE TO TRANSMITTER FACILITY ANTENNA ELEMENTS.

SMALL MAMMAL AND NESTING BIRD STUDIES

On 16 and 17 May 1984 and on 9 through 22 August 1984, IITRI field crews made ELF EM field measurements at 29 measurement points on a total of 10 test and control sites for the small mammal and nesting bird studies. The 10 sites included four sites previously measured and still in use plus six new sites: 1T4, 1T5, 1T6, 1C4, 1C5, and 1C6. Control site 1C5 has since been abandoned by the investigator. The positions of the remaining nine sites relative to the Republic Transmitter Facility antenna are shown on the composite map in Figure A-1. The site numbers listed on the map are those used by IITRI. Table A-1 provides a cross reference of IITRI site numbers, investigator site names, and township, range, and section numbers for the sites.

TABLE A-1. SITE NO. CROSS-REFERENCE

IITRI Site No.	Investigator's Site Name	Location		
		Township	Range	Section(s)
1T1	Leeman's Road	T43N	R29W	23,26
1T2	Cleveland Homestead	T44N	R29W	23,24,25,26
1T4	North Turner Road	T43N	R29W	1
1T5	Ford River North	T43N	R29W	14
1T6	Ford River South	T43N	R29W	14
1C1	Michigamme North	T44N	R31W	12,13
1C3	Michigamme South	T44N	R31W	24
1C4	Panola Plains	T42N	R32W	10,11
1C6	Tachycineta Meadow	T42N	R31W	3

PREVIOUS PAGE IS BLANK

APPENDIX A

SMALL MAMMAL AND NESTING BIRD STUDIES

PREVIOUS PAGE
IS BLANK

APPENDIX C

SOIL ARTHROPOD AND EARTHWORM STUDIES

PREVIOUS PAGE
IS BLANK

SOIL ARTHROPOD AND EARTHWORM STUDIES

On 14 and 21 May 1984 and on 9 and 13 August 1984, IITRI field crews made ELF EM field measurements at two measurement points on two test and control sites for the soil arthropod and earthworm studies. The two sites had been previously measured and are still in use. The positions of these sites relative to the proposed Republic Transmitter Facility antenna elements are shown on the composite map in Figure C-1. The site numbers listed on the map are those used by IITRI. Table C-1 provides a cross-reference of IITRI site numbers, investigator site names, and township, range, and section numbers for the sites.

TABLE C-1. SITE NO. CROSS-REFERENCE

IITRI Site No.	Investigator's Site Name	Location		
		Township	Range	Section(s)
3T2	South Silver Lake	T44W	R29W	25
3C5	Turner Road	T43W	R30W	11

The soil arthropod and earthworm studies will monitor species composition, population age structure, and distribution. The electric and magnetic fields in the earth are considered the most important EM factors influencing soil biota. The electric field in the air is not expected to have a significant impact on the objectives of this study.

Table C-2 shows the site pairing of interest to the investigator and the acceptability of the pair as defined in Section 4.1.

PREVIOUS PAGE IS BLANK

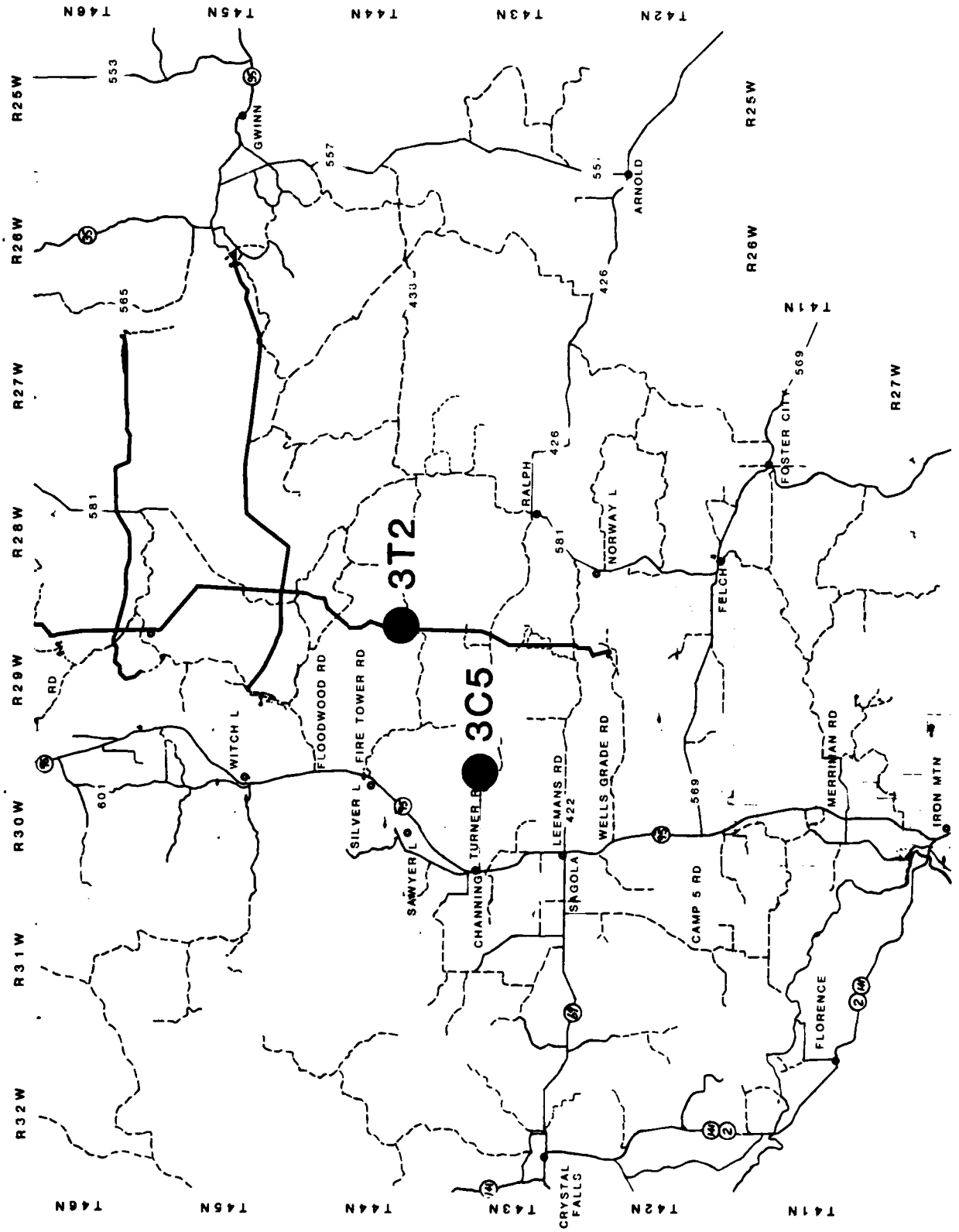


FIGURE C-1. POSITIONS OF TEST AND CONTROL SITES RELATIVE TO TRANSMITTER FACILITY ANTENNA ELEMENTS.

TABLE C-2. SITE PAIRING AND ACCEPTABILITY

Test Site	Control Site	Acceptability
3T1	3C5	Acceptable

Data listed for the magnitudes of the fields produced by the ELF system were estimated at a frequency of 76 Hz (the expected operating frequency) and based on calculations utilizing the proposed location and operating conditions of the Republic Transmitter Facility antenna elements and the distance to each measurement point. Table C-3 presents a summary of the measured 60 Hz and estimated 76 Hz data for 1984 taken at measurement points for each of the sites. Where applicable, 1983 data are also presented for reference.

The ELF EM field exposure criteria were applied to the data by computing the field intensity ratios utilized in mathematical representation of the exposure criteria (see Section 2.1). The results of this effort are illustrated in Table C-4.

The investigator has one acceptable test/control site pair.

TABLE C-3. ELECTRIC FIELD INTENSITIES AND MAGNETIC FLUX DENSITIES[1,2]
Soil Arthropod and Earthworm Studies

Site No.	Meas. Yr.	Transverse E Field, V/M		Longitudinal E Field, mV/M		Magnetic Flux Density, mG	
		76 Hz	60 Hz	76 Hz	60 Hz	76 Hz	60 Hz
3T2	1983	0.1	<0.001	57-65	0.11	4-7.5	<0.001
3T2	1984	0.1	--	57-65	0.12	4-7.5	<0.001
3T2	1984	0.1	<0.001	57-65	0.27	4-7.5	<0.001
3C5	1983	<0.001	<0.001	4.0	0.063	0.03	0.001
3C5	1984	<0.001	--	4.0	0.018	0.03	0.001
3C5	1984	<0.001	<0.001	4.0	0.032	0.03	0.001

[1] Data listed for 76 Hz is estimated based on analysis using the proposed location and operating conditions of the antenna elements along with the distance to each measurement point.

[2] Values shown are magnitudes determined as the square root of the sum of the square of the orthogonal field components.

TABLE C-4. FIELD RATIOS' MAGNITUDE[1]
Soil Arthropod and Earthworm Studies

Site Nos.	Transverse E Field (Air)				Longitudinal E Field (Earth)				Magnetic Flux Density			
	R1	R2	R3	R4	R1	R2	R3	R4	R5	R6	R7	R8
3T2/3C5	100	100	100	1.00	14.25	211	1781	8.44	133	4000	4000	1.00

[1] $R_1 = \frac{T(76\ Hz)}{C(76\ Hz)}$, $R_1 \geq 10$

$R_2 = \frac{T(76\ Hz)}{T(60)}$, $R_2 \geq 10$

$R_3 = \frac{T(76\ Hz)}{C(60)}$, $R_3 \geq 10$

$R_4 = \frac{T(60)}{C(60)}$, $0.1 \leq R_4 \leq 10$.

When a range of values were available for calculating a given ratio, the ratio range was calculated as follows:

High Limit ---> Maximum Numerator Value/Minimum Denominator Value
Low Limit ---> Minimum Numerator Value/Maximum Denominator Value

* Does not meet the exposure criteria.

APPENDIX D

UPLAND FLORA AND SOIL MICROFLORA STUDIES

PREVIOUS PAGE IS BLANK

UPLAND FLORA AND SOIL MICROFLORA STUDIES

On 15 and 21 May 1984 and on 6 and 9 August 1984, IITRI field crews made ELF EM field measurements at 14 measurement points on a total of five test and control sites for upland flora and soil microflora studies. The five sites included three sites previously measured and still in use plus two new sites: 4T4 and 4C3. Control sites 4C2 and 4C3 were abandoned by the investigator in mid-1984. The positions of the remaining three sites relative to the proposed Republic Transmitter Facility antenna elements are shown on the composite map in Figure D-1. The site numbers listed on the map are those used by IITRI. Table D-1 provides a cross-reference of IITRI site numbers, investigator site names, and township, range, and section numbers for the sites.

TABLE D-1. SITE NO. CROSS-REFERENCE

IITRI Site No.	Investigator's Site Name	Location		
		Township	Range	Section(s)
4T2	Martell's Lake (Overhead): ML	T45N	R29W	28
4T4	Martell's Lake (Buried): EP	T45N	R29W	28
4C1	Paint Pond Road Control	T41N	R32W	3, 10

The major themes of the upland flora and microflora studies are the functional and structural aspects of organic material cycling. These studies will investigate and characterize trees, herbaceous plants, and microflora populations. The electric and magnetic fields in the earth are considered important EM factors influencing soil biota and processes. The electric and magnetic fields in the air can influence any object extending above the surface. Since the electric field in the air can be effectively shunted by

PREVIOUS PAGE IS BLANK

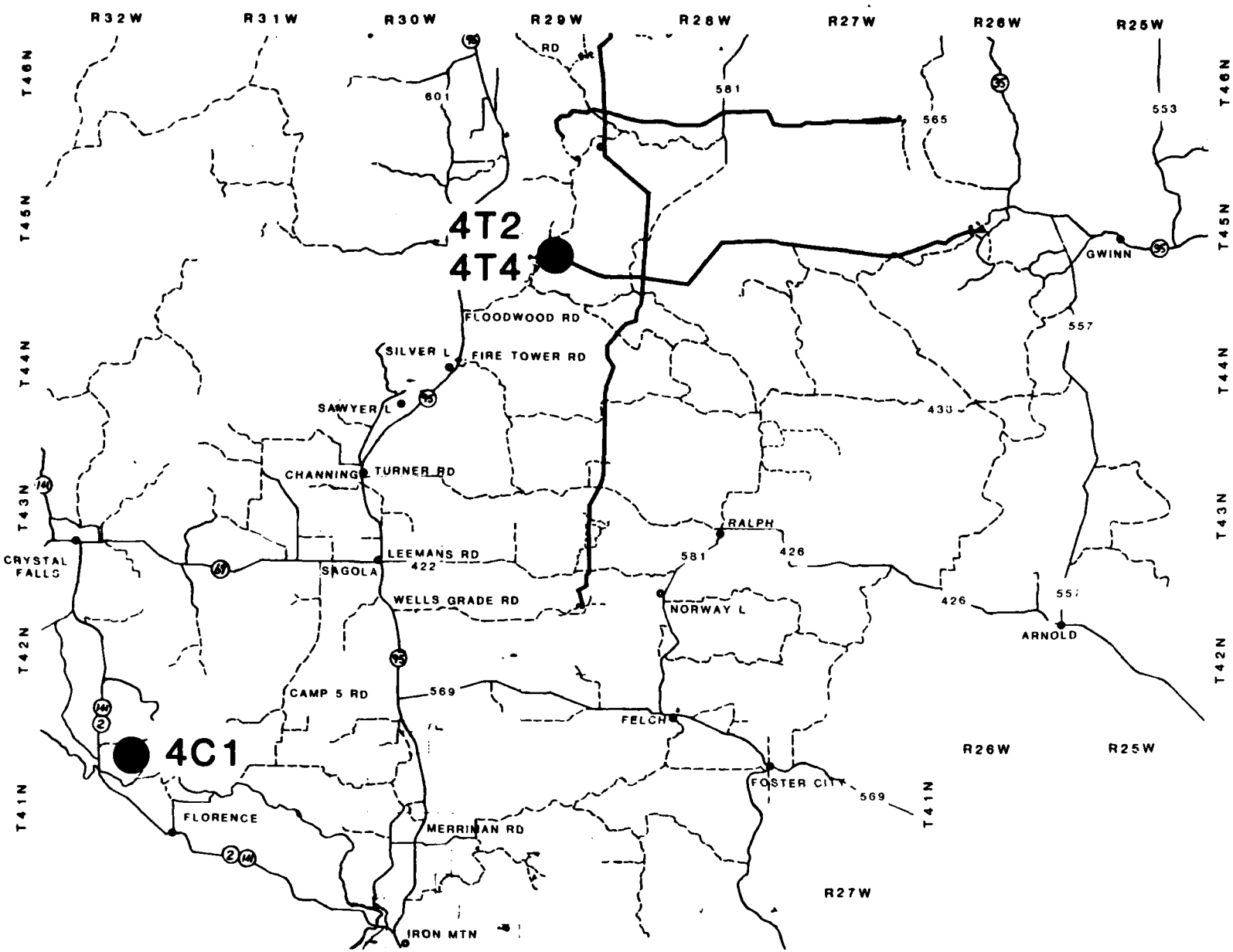


FIGURE D-1. POSITIONS OF TEST AND CONTROL SITES RELATIVE TO TRANSMITTER FACILITY ANTENNA ELEMENTS.

trees or plants on the perimeter of a given study plot, special care was taken in specifying the electric field intensity across the plot.

The investigator has one control site and two test sites. Table D-2 shows the site pairings of interest to the investigator and the acceptability of each pair as defined in Section 4.1.

TABLE D-2. POTENTIAL SITE PAIRING AND ACCEPTABILITY

Test Site	Control Site	Acceptability
4T2	4C1	Conditionally Acceptable
4T4	4C1	Conditionally Acceptable

Data listed for the magnitudes of the fields produced by the ELF system were estimated at a frequency of 76 Hz (the expected operating frequency) and based on calculations utilizing the proposed location and operating conditions of the Republic Transmitter Facility antenna elements and the distance to each measurement point. Table D-3 presents a summary of the measured 60 Hz and estimated 76 Hz data for 1984 taken at measurement points for each of the currently used sites. Where applicable, 1983 data are also presented for reference.

The ELF EM field exposure criteria were applied to the data by computing the field intensity ratios utilized in the mathematical representation of the exposure criteria (see Section 2.1). The results of this effort are illustrated in Table D-4. In the case of control site 4C1, each of the individual measurement points 6, 7, 8, and 9 is compared to the test sites. Measurement points 4C1-1, 2, 3, 4, and 5 (measured in 1983 and early in 1984), bordered the outside perimeter of where the site would be located. From these measurement points and the 69 kV transmission line location, a better defined location for site acceptability was created. Measurement points 4C1-6, 7, 8, and 9 (measured in August 1984) are the boundaries of the study plot marked by the investigator's equipment.

The investigator has two conditionally acceptable test/control site pairs, both utilizing control site 4C1. Because of a 69 kV transmission line

running northeast of the site, the 60 Hz electric field in the ground is highly variable. The investigator's study plot has a ten-to-one variability in electric field in earth across it. Although the measurement points at the northeast side, 4C1-7 and 8, are in an acceptable range for test/control site pairs, measurement points at the southwest side, 4C1-6 and 9, are not in the acceptable range. Therefore, the control site as a whole is conditionally acceptable with the two test sites.

TABLE D-3. ELECTRIC FIELD INTENSITIES AND MAGNETIC FLUX DENSITIES[1,2]
Upland Flora and Soil Microflora Studies

Site No.	Meas. Pt.	Meas. Yr.	Transverse E Field (Air), V/M		Longitudinal E Field (Earth), mV/M		Magnetic Flux Density, mG	
			76 Hz	60 Hz	76 Hz	60 Hz	76 Hz	60 Hz
4C1	1	1983	--	<0.001	--	0.27	--	0.011
4C1	1	1984	--	--	--	0.29	--	0.008
4C1	2	1983	--	<0.001	--	0.56	--	0.18
4C1	3	1983	--	<0.001	--	0.004	--	0.001
4C1	3	1984	--	--	--	--	--	0.001
4C1	4	1983	--	--	--	0.16	--	0.009
4C1	5	1983	--	--	--	0.38	--	0.005
4C1	5	1984	--	--	--	0.18	--	0.002
4C1	6	1984	--	0.003	--	0.020	--	0.003
4C1	7	1984	--	0.006	--	0.14	--	0.003
4C1	8	1984	--	0.004	--	0.10	--	0.003
4C1	9	1984	--	<0.001	--	0.010	--	0.003
4T2	1	1983	--	<0.001	--	0.24	--	<0.001
4T2	2	1983	--	--	--	0.25	--	<0.001
4T2	3	1984	--	0.001	--	0.51	--	0.002
4T4	1	1984	--	<0.001	--	0.46	--	0.002
4T4	2	1984	--	0.003	--	0.35	--	0.003
4T4	3	1984	--	0.001	--	0.59	--	0.004
4T4	4	1984	--	0.003	--	0.72	--	0.004

[1] Data listed for 76 Hz is estimated based on analysis using the proposed location and operating conditions of the antenna elements along with the distance to each measurement point.

[2] Values shown are magnitudes determined as the square root of the sum of the square of the orthogonal field components.

TABLE D-4. FIELD RATIOS' MAGNITUDE[1]
Upland Flora and Soil Microflora Studies

Compared Site Nos.	Transverse E Field (Air)				Longitudinal E Field (Earth)				Magnetic Flux Density			
	R1	R2	R3	R4	R1	R2	R3	R4	R1	R2	R3	R4
4T2/4C1-6	35000	35000	11700	0.33	300	117	3000	26.0*	5000	2500	1670	0.67
4T2/4C1-7	35000	35000	5800	0.17	300	117	428	3.6	5000	2500	1670	0.67
4T2/4C1-8	35000	35000	8800	0.25	300	117	600	5.1	5000	2500	1670	0.67
4T2/4C1-9	35000	35000	35000	1.00	300	117	6000	51.0*	5000	2500	1670	0.67
4T4/4C1-6	35000	11700	11700	0.33	300	83	3000	18.0-36.0*	5000	1250	1670	0.67-1.33
4T4/4C1-7	35000	11700	5800	0.17-0.50	300	83	430	2.5-5.1	5000	1250	1670	0.67-1.33
4T4/4C1-8	35000	11700	8800	0.25-0.75	300	83	600	3.5-7.2	5000	1250	1670	0.67-1.33
4T4/4C1-9	35000	11700	35000	1.00-3.00	300	83	6000	35.0-72.0*	5000	1250	1670	0.67-1.33

[1] $R_1 = \frac{T(76\ Hz)}{C(76\ Hz)}$, $R_1 \geq 10$

$R_2 = \frac{T(76\ Hz)}{T(60)}$, $R_2 \geq 10$

$R_3 = \frac{T(76\ Hz)}{C(60)}$, $R_3 \geq 10$

$R_4 = \frac{T(60)}{C(60)}$, $0.1 \leq R_4 \leq 10$.

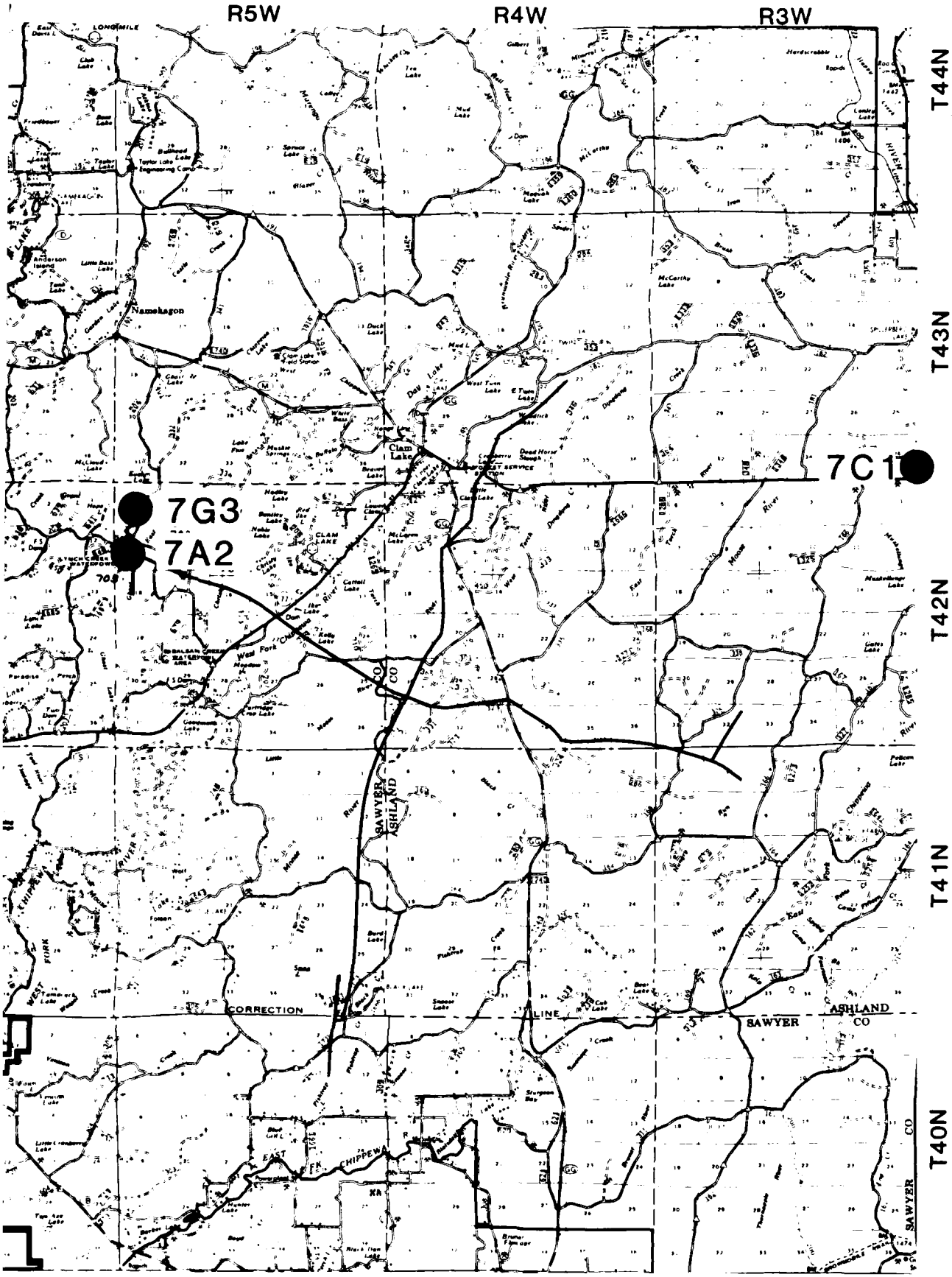
When a range of values were available for calculating a given ratio, the ratio range was calculated as follows:

High Limit ---> Maximum Numerator Value/Minimum Denominator Value
Low Limit ---> Minimum Numerator Value/Maximum Denominator Value

* Does not meet the exposure criteria.

APPENDIX E

AQUATIC ECOSYSTEM STUDIES



IGURE G-1. POSITIONS OF TEST AND CONTROL SITES RELATIVE TO TRANSMITTER FACILITY ANTENNA ELEMENTS.

SLIME MOLD STUDIES

On 22 and 24 May 1984 and on 17 and 19 September 1984, IITRI's field crews made ELF EM field measurements at a total of four test and control sites for the slime mold (Physarum polycephalum) study. A cumulative total of seven test and control sites have been identified for the slime mold study since the fall of 1982. Of the four sites measured in 1984, three had previously been documented and one new test site was established. The currently active sites are 7A2, 7G3, and 7C1. The positions of these sites relative to the Clam Lake (Wis.) Transmitter Facility antenna elements are shown on the composite map in Figure G-1. The site numbers listed on the map are those used by IITRI. Table G-1 provides a cross-reference of IITRI site numbers, investigator site names, and township, range, and section numbers for the sites.

TABLE G-1. SITE NO. CROSS-REFERENCE

IITRI Site No.	Investigator's Site Name	Location		
		Township	Range	Section(s)
7A2	Antenna No. 2	T42N	R5W	7
7C1	Control No. 1	T43N	R2W	31
7G3	Ground No. 3	T42N	R5W	7

The slime mold study has been designed to monitor for ELF EM field exposure effects on the respiration and mitosis of the slime mold, Physarum polycephalum. The electric and magnetic fields in the earth are considered important EM factors influencing soil biota. The electric field in the air is not expected to have a significant impact on the objectives of this study.

Table G-2 shows the site pairings of interest and the acceptability of each pair as defined in Section 4.1.

APPENDIX G

SLIME MOLD STUDIES

PREVIOUS PAGE
IS BLANK

TABLE F-4. FIELD RATIOS' MAGNITUDE[1]
Soil Amoeba Studies

Compared Site Nos.	Transverse E Field (Air)				Longitudinal E Field (Earth)				Magnetic Flux Density			
	R1	R2	R3	R4	R1	R2	R3	R4	R1	R2	R3	R4
6T3/6C2	15000	15000	15000	1.000	130	500	107	0.213	500	5000	1250	0.250
6T5/6C2	15000	15000	15000	1.000	130	241	107	0.443	500	1667	1250	0.750
1T1-2/6/C2	15000	15000	15000	1.000	130	3611	107	0.030**	500	5000	1250	0.250
1T1-6,7/6C2	15000	15000	15000	1.000	130	5000	107	0.18-0.21	500	5000	1250	0.250

[1] $R_1 = \frac{T(76\ Hz)}{C(76\ Hz)}$, $R_1 \geq 10$

$R_2 = \frac{T(76\ Hz)}{T(60)}$, $R_2 \geq 10$

$R_3 = \frac{T(76\ Hz)}{C(60)}$, $R_3 \geq 10$

$R_4 = \frac{T(60)}{C(60)}$, $0.1 \leq R_4 \leq 10$.

When a range of values were available for calculating a given ratio, the ratio range was calculated as follows:

High Limit ---> Maximum Numerator Value/Minimum Denominator Value
Low Limit ---> Minimum Numerator Value/Maximum Denominator Value

* Does not meet the exposure criteria.

TABLE F-3. ELECTRIC FIELD INTENSITIES AND MAGNETIC FLUX DENSITIES[1,2]
Soil Amoeba Studies

Site No.	Meas. Pt.	Meas. Yr.	Transverse E Field (Air), V/M		Longitudinal E Field (Earth), mV/M		Magnetic Flux Density, mG	
			76 Hz	60 Hz	76 Hz	60 Hz	76 Hz	60 Hz
6T3	1	1983	15.0	0.001	65.0	0.087	10.0	0.002
6T3	2	1984	15.0	--	65.0	0.13	10.0	0.002
6T5	1	1984	15.0	<0.001	65.0	0.27	10.0	0.006
6C2	1	1983	<0.001	<0.001	0.5	0.32	0.02	0.004
6C2	1	1984	<0.001	--	0.5	0.61	0.02	0.008
1T1	2	1984	15.0	<0.001	65.0	0.018	10.0	0.002
1T1	6,7	1984	15.0	0.001	65.0	0.11-0.13	10.0	0.002

[1] Data listed for 76 Hz is estimated based on analysis using the proposed location and operating conditions of the antenna elements along with the distance to each measurement point.

[2] Values shown are magnitudes determined as the square root of the sum of the square of the orthogonal field components.

Table F-2 shows the site pairings of interest and the acceptability of each pair as defined in Section 4.1.

TABLE F-2. POTENTIAL SITE PAIRINGS AND ACCEPTABILITY

Test Site	Control Site	Site Pair Acceptability
6T3	6C2	Acceptable
6T5	6C2	Acceptable

Data listed for the magnitudes of the fields produced by the ELF system were estimated at a frequency of 76 Hz (the expected operating frequency) and based on calculations utilizing the proposed location and operating conditions of the Republic Transmitter Facility antenna elements and the distance to each measurement point. Table F-3 presents a summary of the measured 60 Hz and estimated 76 Hz data for 1984 taken at measurement points for each of the currently used sites. Where applicable, 1983 data are also presented for reference.

The ELF EM field exposure criteria were applied to the data by computing the field intensity ratios utilized in the mathematical representation of the exposure criteria (see Section 2.1). The results of this effort are illustrated in Table F-4.

There is a possibility that test site 6T3 may be relocated in the same general area. As guidelines for the EM exposure in this area, three measurement points of another investigator are included in Tables F-3 and F-4. Measurement point 1T1-2 is on the ROW of the antenna 0.75 miles south of the present location of test site 6T3. Measurement points 1T1-6 and 1T1-7 are on the ROW less than 0.1 miles north of the present test site location. As Table F-4 shows, the test site would be acceptable 0.1 miles north of its present location (near 1T1-6 or 1T1-7); however, the test site would be conditionally acceptable if relocated 0.75 miles south (near 1T1-2).

If test site 6T3 remains near its original location as of 1984, the investigator has two acceptable test/control site pairs.

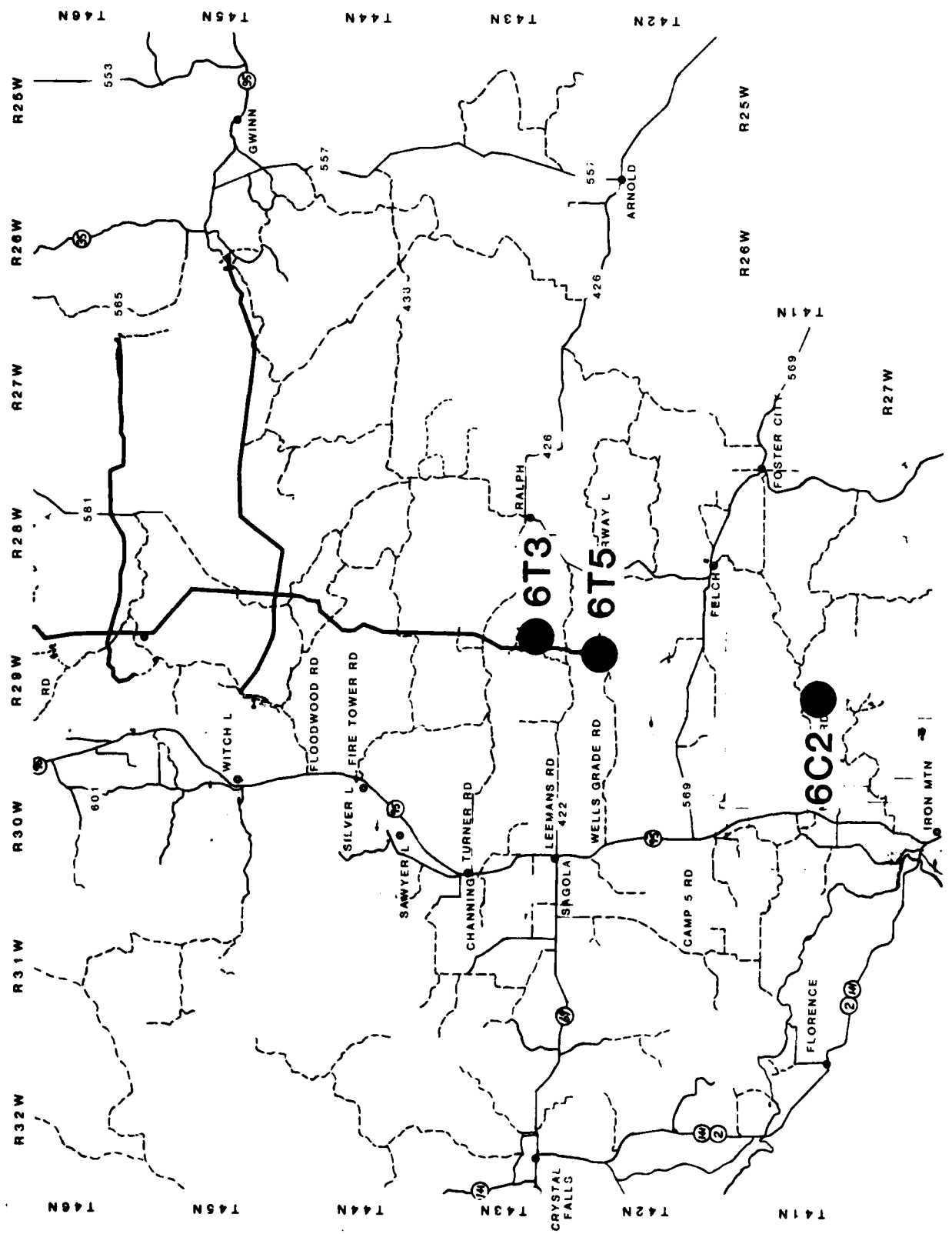


FIGURE F-1. POSITIONS OF TEST AND CONTROL SITES RELATIVE TO TRANSMITTER FACILITY ANTENNA ELEMENTS.

SOIL AMOEBA STUDIES

On 14 May 1984 and on 8, 10, 13, and 15 August 1984, IITRI field crews made ELF EM field measurements at a total of four test and control sites. The four sites included one site previously measured and still in use plus three new sites: 6T4, 6T5, and 6C2. Of the four sites, three remain active. The positions of these three sites relative to the proposed Republic Transmitter Facility antenna elements are shown on the composite map in Figure F-1. The site numbers listed on the map are those used by IITRI. Table F-1 provides a cross-reference of IITRI site numbers, investigator site names, and township, range, and section numbers for the sites.

TABLE F-1. SITE NO. CROSS-REFERENCE

IITRI Site No.	Investigator's Site Name	Location		
		Township	Range	Section(s)
6T3	Leeman's Road	T43N	R29W	23
6T5	Wells Grade Ground	T42N	R22W	2
6C2	Merriman Truck Trail Control	T41N	R29W	21

The objectives for this study are to monitor population and species characteristics, cell cycle, cropping efficiency, and distribution in the soil. The electric and magnetic fields in the earth are considered the most important EM factors to be examined. The electric field in the air is not expected to have a significant impact on the objectives of this study.

Several of the above objectives require the use of a buried culture chamber at the study site. IITRI plans to characterize the relationship of internal EM fields to those present in the environment.

PREVIOUS PAGE IS BLANK

APPENDIX F

SOIL AMOEBA STUDIES

PREVIOUS PAGE
IS BLANK

TABLE E-4. FIELD RATIOS' MAGNITUDE[1]
Aquatic Ecosystem Studies

Compared Site Nos.	Transverse E Field (Air)				Longitudinal E Field (Earth)				Magnetic Flux Density			
	R1	R2	R3	R4	R1	R2	R3	R4	R1	R2	R3	R4
5T2-1/5C1-1	--	--	--	--	>7.5	>194	>22	>0.081*-0.115	>107	>5000	>625	>0.125
5T2-2/5C1-3	--	--	--	--	8.5	262	23	0.087*	213	100000	909	0.091*
5T1-2/5C1-3	--	--	--	--	>5.9	>214	>16	>0.050-0.073*	>43	>2000	>182	>0.091*
5T4/5C1-3	--	--	--	--	>4.5	>185	>12	>0.065*	>20	950	>86	>0.091*
5T3/5C1-4	--	--	--	--	>7.5	>231	>22	0.081*-0.10	>106	>2500	>625	0.12-0.29
5T3/5C5	--	--	--	--	>4.9	>231	>968	3.5-4.2	>71	>2500	>2500	0.050*-1.0
5T3/5C3	--	--	--	--	>11	>231	>1333	4.9-5.8	>135	>2500	>1667	0.33-0.67
5T3/5C14	--	--	--	--	>8.5	>231	>250	0.92-1.1	>106	2500	>238	0.05*-0.10
5T6/5C14	--	--	--	--	>4.8	> 90	>14	0.137-0.168	>23	>1100	>138	0.125-0.143

[1] $R_1 = \frac{T(76\ Hz)}{C(76\ Hz)}$, $R_1 \geq 10$

$R_2 = \frac{T(76\ Hz)}{T(60)}$, $R_2 \geq 10$

$R_3 = \frac{T(76\ Hz)}{C(60)}$, $R_3 \geq 10$

$R_4 = \frac{T(60)}{C(60)}$, $0.1 \leq R_4 \leq 10$.

When a range of values were available for calculating a given ratio, the ratio range was calculated as follows:

High Limit ---> Maximum Numerator Value/Minimum Denominator Value
Low Limit ---> Minimum Numerator Value/Maximum Denominator Value

* Does not meet the exposure criteria.

TABLE E-3. ELECTRIC FIELD INTENSITIES AND MAGNETIC FLUX DENSITIES[1,2] Aquatic Ecosystem Studies

Site No.	Meas. Pt.	Meas. Yr.	Traverse E Field (Air), V/M		Longitudinal E Field (Earth), mV/M		Magnetic Flux Density, mG	
			76 Hz	60 Hz	76 Hz	60 Hz	76 Hz	60 Hz
5C1	1	1983	<0.001	0.002	8.0	1.47	0.047	0.008
5C1	1	1984	<0.001	<0.001	8.0	2.7	0.047	0.008
5C1	3	1983	<0.001	0.001	8.0	1.3	0.047	0.004
5C1	3	1984	<0.001	--	8.0	3.0	0.047	0.011
5C1	4	1984	<0.001	--	8.0	2.5	0.047	0.007
5C1	4	1984	<0.001	<0.001	8.0	2.7	0.047	0.008
5C3	1	1983	<0.001	0.002	8.0	0.049	0.037	0.003
5C3	1	1984	<0.001	--	8.0	--	0.037	0.003
5C3	1	1983	<0.001	0.003	8.0	0.045	0.037	0.003
5C5	1	1983	<0.001	0.001	15.0	0.076	0.07	0.002
5C5	1	1984	<0.001	<0.001	15.0	0.062	0.07	0.002
5C14	1	1984	--	--	--	0.17	0.047	0.013
5C14	1	1984	--	0.033	--	0.24	0.047	0.021
5T1	2	1983	1.0	<0.001	47.0	0.18	2.0	<0.001
5T1	2	1984	1.0	--	47.0	0.15	2.0	0.001
5T1	2	1984	1.0	--	47.0	0.22	2.0	0.001
5T2	1	1984	--	--	60.0	0.22	5.0	0.001
5T2	1	1984	--	--	60.0	0.31	5.0	0.001
5T2	2	1984	--	--	68.0	0.26	10.0	0.001
5T3	1	1984	--	--	60.0	0.22	5.0	0.001
5T3	1	1984	--	--	60.0	0.26	5.0	0.002
5T4	1	1984	--	--	36.0	0.17	0.95	0.001
5T4	1	1984	--	--	36.0	0.20	0.95	0.001
5T6	1	1984	--	--	38.0	0.37	1.1	0.001
5T6	1	1984	--	<0.001	38.0	0.42	1.1	0.001

[1] Data listed for 76 Hz is estimated based on analysis using the proposed location and operating conditions of the antenna elements along with the distance to each measurement point.

[2] Values shown are magnitudes determined as the square root of the sum of the square of the orthogonal field components.

Table E-2 shows the site pairings of interest and the acceptability of each pair as defined in Section 4.1.

TABLE E-2. POTENTIAL SITE PAIRINGS AND ACCEPTABILITY

Test Site	Control Site	Site Pair Acceptability
5T1-2	5C1-3	Conditionally Acceptable
5T2-1	5C1-1	Conditionally Acceptable
5T2-2	5C1-3	Conditionally Acceptable
5T3	5C1-4	Conditionally Acceptable
	5C3	Acceptable
	5C5	Conditionally Acceptable
	5C14	Conditionally Acceptable
5T4	5C1-3	Conditionally Acceptable
5T6	5C1-4	Conditionally Acceptable

Data listed for the magnitudes of the fields produced by the ELF system were estimated at a frequency of 76 Hz (the expected operating frequency) and based on calculations utilizing the proposed location and operating conditions of the Republic Transmitter Facility antenna elements and the distance to each measurement point. Table E-3 presents a summary of the measured 60 Hz and estimated 76 Hz data for 1984 taken at measurement points for each of the currently used sites. Where applicable, 1983 data are also presented for reference.

The ELF EM field exposure criteria were applied to the data by computing the field intensity ratios utilized in the mathematical representation of the exposure criteria. The results of this effort are illustrated in Table E-4.

The investigator has adequate test/control site pairings to conduct experiments.

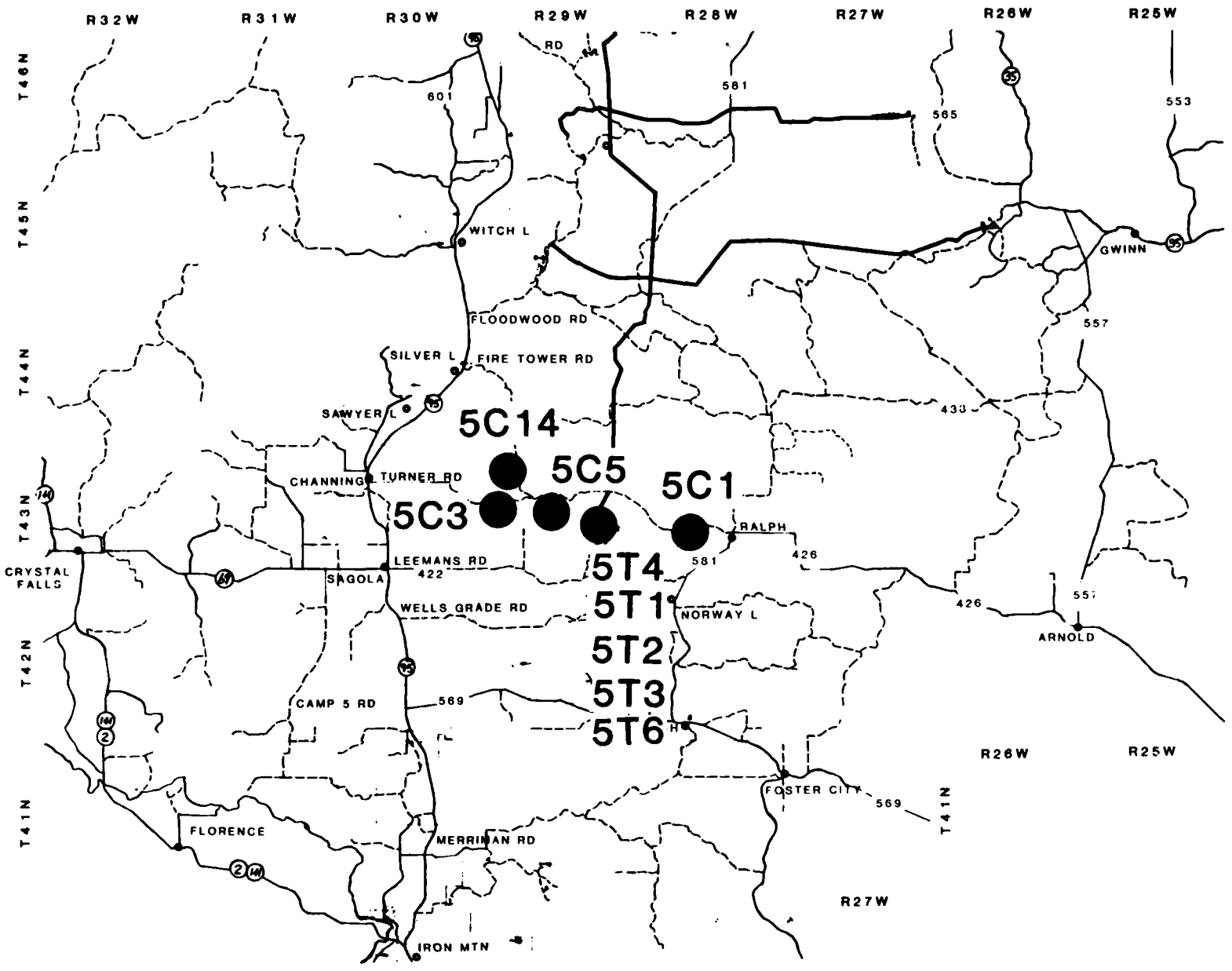


FIGURE E-1. POSITIONS OF TEST AND CONTROL SITES RELATIVE TO TRANSMITTER FACILITY ANTENNA ELEMENTS.

AQUATIC ECOSYSTEM STUDIES

On 5 and 16 May 1984 and on 21 and 22 August 1984, IITRI field crews made ELF EM field measurements at 14 measurement points at a total of 10 test and control sites for the aquatic ecosystem studies. The 10 sites included four sites previously measured and still in use plus six new sites: 5T2, 5T3, 5T4, 5T5, 5T6, and 5C14. Test site 5T5 was abandoned by the investigator during 1984. The positions of the remaining nine sites relative to the proposed Republic Transmitter Facility antenna elements are shown on the composite map in Figure E-1. The site numbers listed on the map are those used by IITRI. Table E-1 provides a cross-reference of IITRI site numbers, study titles, and township, range, and section numbers for the sites.

TABLE E-1. SITE NO. CROSS-REFERENCE

IITRI Site No.	Study Title	Location		
		Township	Range	Section(s)
5T1-2	Invertebrates	T43N	R29W	14
5T2-1	Ambient Monitoring	T43N	R29W	14
5T2-2	Periphyton	T43N	R29W	14
5T3	Fish	T43N	R29W	14
5T4	Invertebrates	T43N	R29W	14
5T6	Parasites	T43N	R29W	13
5C1-1	Ambient Monitoring	T43N	R29W	21
5C1-3	Periphyton/Invertebrates	T43N	R29W	21
5C1-4	Fish/Parasite	T43N	R29W	21
5C3	Fish	T43N	R29W	18
5C5	Fish	T43N	R29W	16
5C14	Fish	T43N	R29W	8

PREVIOUS PAGE IS BLANK

TABLE G-2. POTENTIAL SITE PAIRINGS AND ACCEPTABILITY

Test Site	Control Site	Site Pair Acceptability
7A2	7C1	Acceptable
7G3	7C1	Acceptable

Data listed for the magnitudes of the EM fields produced by the ELF system were determined as the square root of the sum of the squares of the orthogonal field components measured. Data for 76 Hz represent values determined by summation of the magnitudes of the fields produced by the east-west and north-south antennas at 300 amperes. Table G-3 presents a summary of the measured 60 Hz and 76 Hz data for 1984 taken at measurement points for each of the sites. Where applicable, 1983 data are also presented for reference.

The ELF EM field exposure criteria were applied to the data by computing the field intensity ratios utilized in the mathematical representation of the exposure criteria (see Section 2.1). The results of this effort are illustrated in Table G-4.

This study makes use of buried culture chambers. The chamber has three functions: to restrict the slime mold so that their reproduction cycle can be easily monitored; to prevent contamination from the environment; and to produce an electric field within the chamber that corresponds to the electric field in earth. With this test setup, the investigator is able to approximate laboratory conditions in a field study.

Table G-5 shows the voltage measured across a chamber terminal that corresponds to a produced electric field within the chamber. Appendix L explains this relationship.

TABLE G-3. EXTERNAL ELECTRIC FIELD INTENSITIES AND MAGNETIC FLUX DENSITIES[1,2]
Slime Mold Studies

Site No.	Meas. Pt.	Meas. Yr.	Transverse E Field (Air), V/M		Longitudinal E Field (Earth), mV/M		Magnetic Flux Density, mG	
			76 Hz	60 Hz	76 Hz	60 Hz	76 Hz	60 Hz
7A1	1	1982	--	--	188.0	0.092	184.0	0.033
7A1	1	1983[a]	--	--	157.0	0.116	163.0	0.077
7A1	1	1983[b]	--	--	164.0	0.13	149.0	0.019
7A1	1	1984	0.17	<0.001	156.0	0.11	153.0	0.030
7A2	1	1984	--	--	204.0	0.035	45.0	0.002
7A2	1	1984	0.035	<0.001	239.0	0.052	314.0	<0.001
7C1	1	1982	--	--	1.8	0.062	0.026	0.002
7C1	1	1983	--	--	1.9	0.070	0.025	<0.001
7C1	1	1984	--	--	2.2	0.099	0.025	<0.001
7G3	1	1983	--	--	1860.0	0.091	5.2	<0.001
7G3	1	1984	1.5	<0.001	1510.0	0.13	5.6	0.001

[1] Values shown are magnitudes determined as the square root of the sum of the squares of the orthogonal field components measured.

[a] Before hole was dug.

[b] After hole was dug.

TABLE G-4. RATIO MAGNITUDES FOR EXTERNAL FIELDS[1]
Slime Mold Studies

Compared: Site No.	Transverse E Field (Air)				Longitudinal E Field (Earth)				Magnetic Flux Density			
	R1	R2	R3	R4	R1	R2	R3	R4	R1	R2	R3	R4
7A1/7C1	170	170	170	1.000	71	1418	1576	1.111	6120	5100	153000	30.000*
7A2/7C1	>35	>35	>35	1.000	>93	>3923	>2061	0.354-0.525	>1800	>22500	>45000	1.000-2.000
7G3/7C1	1500	15000	15000	1.000	686	11615	15253	1.313	224	5600	5600	1.000

[1] $R_1 = \frac{T(76\ Hz)}{C(76\ Hz)}$, $R_1 \geq 10$

$R_2 = \frac{T(76\ Hz)}{T(60)}$, $R_2 \geq 10$

$R_3 = \frac{T(76\ Hz)}{C(60)}$, $R_3 \geq 10$

$R_4 = \frac{T(60)}{C(60)}$, $0.1 \leq R_4 \leq 10$.

When a range of values were available for calculating a given ratio, the ratio range was calculated as follows:

High Limit ---> Maximum Numerator Value/Minimum Denominator Value
Low Limit ---> Minimum Numerator Value/Maximum Denominator Value

* Does not meet the exposure criteria.

TABLE G-5. CULTURE CHAMBER AND EARTH ELECTRIC FIELD INTENSITIES (76 Hz)
Slime Mold Studies

Site No.	Chamber	Meas. Yr.	Chamber Voltage, mV	Chamber E Field, mV/m	Longitudinal E Field (Earth)[1], mV/m
7A1	West(A)	1984	4.8	30.97	166.25±14.93
	East(B)		13.5	87.10	
7A2	West	1984	3.0	19.35	221.50±24.75
	East		4.2	27.10	
7C1	#1	1984	0.030	0.19	1.97±0.21
	#2		0.010	0.06	
7G3	North	1984	14.5	93.55	1,685±247.49
	South		16.7	107.74	

[1] Mean ± standard deviation for 1982-1984 data, see Table 1.

The electromagnetic field exposure criteria were also applied to the electric field inside the chamber by computing the field intensity ratios utilized in mathematical representation of exposure criteria (see Section 2.1). The results are of this effort illustrated in Table G-6.

The investigator can pair either of the test sites with the control site and have an acceptable site pair in terms of EM exposure.

TABLE G-6. EXPOSURE RATIO FOR CULTURE CHAMBER
Slime Mold Studies

Compared: Chamber No.	Electric Fields[1] R1	R2	R3	R4
7A1 West(A)/7C1#1	160	4800	4364	0.909*
7A1 West(A)/7C1#2	480	4800	9600	2.000
7A1 East/7C1#1	450	13500	12273	0.909*
7A1 East/7C1#2	1350	13500	27000	2.000
7A2 West/7C1#1	100	3000	2727	0.909*
7A2 West/7C1#2	300	3000	6000	2.000
7A2 East/7C1#1	140	4200	3818	0.909*
7A2 East/7C1#2	420	4200	8400	2.000
7G3 North/7C1#1	483	14500	13182	0.909*
7G3 North/7C1#2	1450	14500	29000	2.000
7G3 South/7C1#1	557	16700	15182	0.909*
7G3 South/7C1#2	1670	16700	33400	2.000

[1] $R_1 = \frac{T(76\ Hz)}{C(76\ Hz)}$, $R_1 \geq 10$

$R_2 = \frac{T(76\ Hz)}{T(60)}$, $R_2 \geq 10$

$R_3 = \frac{T(76\ Hz)}{C(60)}$, $R_3 \geq 10$

$R_4 = \frac{T(60)}{C(60)}$, $0.1 \leq R_4 \leq 10$.

When a range of values were available for calculating a given ratio, the ratio range was calculated as follows:

High Limit ---> Maximum Numerator Value/Minimum Denominator Value
Low Limit ---> Minimum Numerator Value/Maximum Denominator Value

* Does not meet the exposure criteria.

APPENDIX H

WETLAND STUDIES

WETLAND STUDIES

On 23 May 1984, 20 September 1984, and 15 through 19 October 1984, IITRI field crews made ELF EM field measurements at 66 measurement points on a total of 11 test, control, and intermediate sites for the wetland studies. The 11 sites included nine sites previously measured and still in use plus two new sites: 8A4 and 8C4. The new sites replace 8A1 and 8C1. The positions of these 11 sites relative to the Clam Lake (Wis.) Transmitter Facility antenna elements are shown on the composite map in Figure H-1. The site numbers listed on the map are those used by IITRI. Table H-1 provides a cross-reference of IITRI site numbers, investigator site names, and township, range, and section numbers for the sites.

TABLE H-1. SITE NO. CROSS-REFERENCE

IITRI Site No.	Investigator's Site Name	Location		
		Township	Range	Section(s)
8A2	UW Site 22 Antenna	T42N	R4W	31
8A3	UW Site 40 Antenna	T42N	R5W	17
8A4	UW Site 21.2 Antenna	T41N	R5W	1
8G1	UW Site 10.1 Ground	T43N	R4W	22
8G2	UW Site 10.2 Ground	T43N	R4W	22
8C2	UW Site 20 Control	T40N	R3W	10
8C3	UW Site 41 Control	T40N	R3W	2
8C4	UW Site 50 Control	T40N	R3W	10
8M2	UW Site 2 Intermediate	T41N	R4W	19
8M3	UW Site 7 Intermediate	T41N	R4W	33
8M4	UW Site 11 Intermediate	T43N	R4W	36

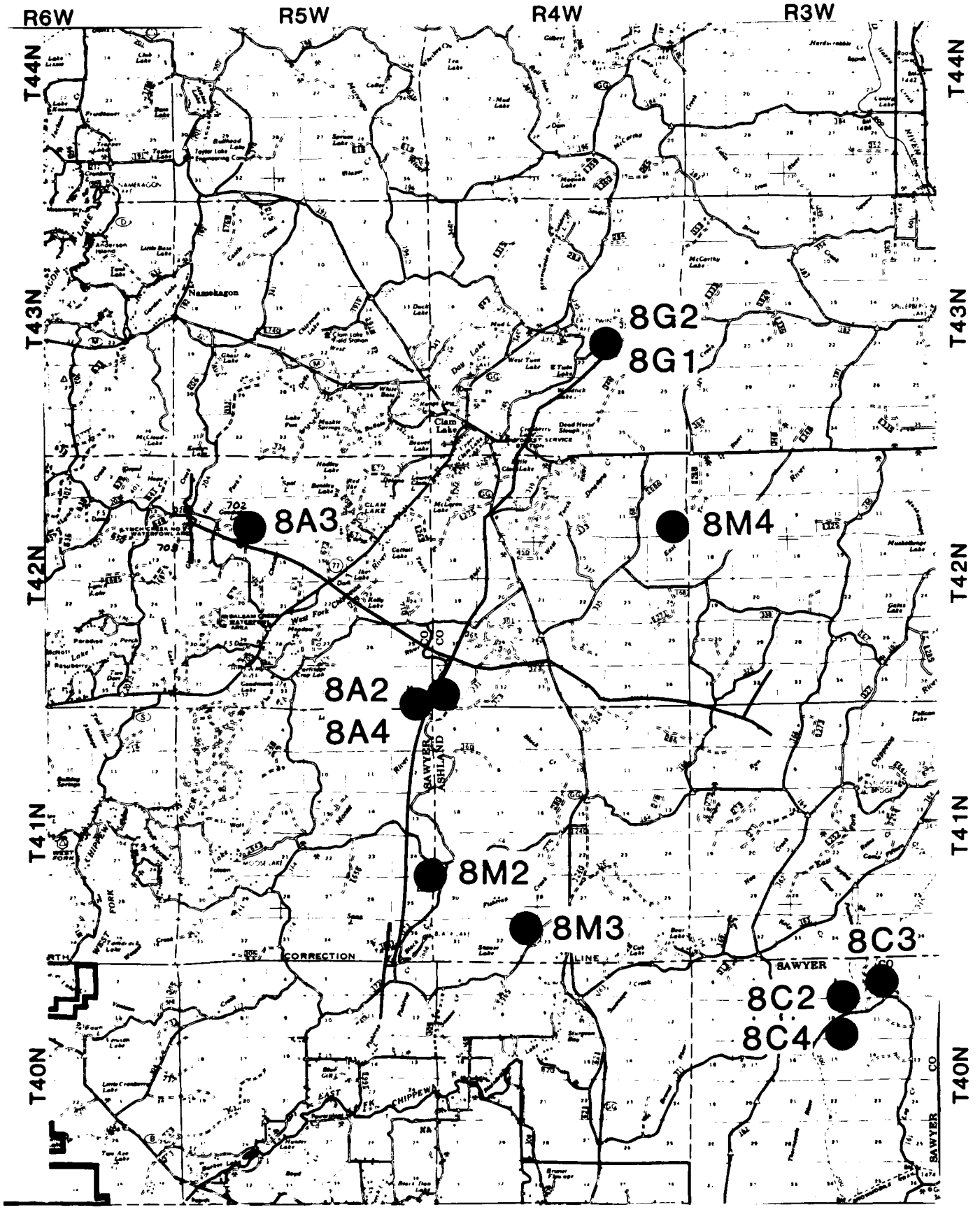


FIGURE H-1. POSITIONS OF TEST AND CONTROL SITES RELATIVE TO TRANSMITTER FACILITY ANTENNA ELEMENTS.

The wetland study will examine the competitive ability of three types of wetland plants (herbs, shrubs, and trees) by examining the organismal characteristics of leaf diffusion and cation transport. The functional operation of the decomposer community will also be assessed by studying the decomposition rate of standardized cellulose material. The electric and magnetic fields in the earth are considered important EM factors influencing wetland biota and processes. The electric and magnetic fields in the air can influence any object extending above the surface. Since the electric field in the air can be effectively shunted by trees or plants on the perimeter of a given study plot, special care was taken in specifying the electric field intensity across the plot. The specific design of the study plots (long and narrow) and their orientation (parallel to the antenna) diminish the need for field gradient measurements across the width (4 m) of the study plots. However, data were taken at measurement points along the length (60 m) of the plots.

Table H-2 shows the site pairings of interest and the acceptability of each pair as defined in Section 4.1.

Data listed for the magnitudes of the fields produced by the ELF system were determined as the square root of the sum of the squares of the orthogonal field components measured. Data for 76 Hz represent worst case values determined by summation of the magnitudes of the fields produced by the east-west and north-south antennas operating at 300 amperes. Table H-3 presents a summary of the measured 60 Hz and 76 Hz data taken at measurement points for each of the currently used sites. Where applicable, 1983 data are also presented for reference.

Although measurements were made on the same sites, similarily numbered measurement points do not correspond from 1983 to 1984. For example, on site 8A2 measurement point -2 (1983) is not the same as measurement point -2 (1984). Measurement points used in 1984 correspond to numbered flags currently on study sites.

TABLE H-2. POTENTIAL SITE PAIRINGS AND ACCEPTABILITY

Test Site	Control Site	Site Pair Acceptability
8A2	8C2	Conditionally Acceptable
8A2	8C3	Conditionally Acceptable
8A2	8C4	Acceptable
8A3	8C2	Acceptable
8A3	8C3	Acceptable
8A3	8C4	Acceptable
8A4	8C2	Acceptable
8A4	8C3	Acceptable
8A4	8C4	Acceptable
8G1	8C2	Conditionally Acceptable
8G1	8C3	Conditionally Acceptable
8G1	8C4	Acceptable
8G2	8C2	Conditionally Acceptable
8G2	8C3	Acceptable
8G2	8C4	Acceptable

TABLE H-3. ELECTRIC FIELD INTENSITIES AND MAGNETIC FLUX DENSITIES[1]
Wetland Studies (Page 1 of 4)

Site No.	Meas.[2] Pt.	Meas. Yr.	Transverse E Field (Air), V/M		Longitudinal E Field (Earth), mV/M		Magnetic Flux Density, mG	
			76 Hz	60 Hz	76 Hz	60 Hz	76 Hz	60 Hz
8A2	1	1983	0.189	<0.001	149.0	0.081	1.95	0.002
8A2	2	1983	0.150	<0.001	93.0	0.044	7.55	<0.001
8A2	3	1983	0.115	<0.001	49.0	0.028	8.14	0.002
8A2	-1	1984	0.166	<0.001	152.0	0.157	7.4	0.0016
8A2	-2	1984	0.189	<0.001	130.0	0.159	7.3	0.0016
8A2	-3	1984	0.199	<0.001	138.0	0.168	7.3	0.0016
8A2	-4	1984	0.38	<0.001	230.0	0.27	7.4	0.0015
8A2	-5	1984	0.67	<0.001	450.0	0.37	7.4	0.0014
8A2	-6	1984	0.38	<0.001	190.0	0.192	7.4	0.0011
8A3	1	1983	0.129	<0.001	140.0	0.065	22.05	0.001
8A3	2	1983	0.150	<0.001	149.0	0.071	21.05	0.001
8A3	3	1983	0.170	<0.001	160.0	0.070	23.05	0.001
8A3	-7	1984	0.160	<0.001	139.0	0.056	22.6	0.0014
8A3	-1	1984	0.152	<0.001	145.0	0.057	19.2	0.0015
8A3	-2	1984	0.194	<0.001	159.0	0.052	19.6	0.0012
8A3	-3	1984	0.171	<0.001	152.0	0.061	19.5	0.0016
8A3	-4	1984	0.166	<0.001	134.0	0.059	19.8	0.0013
8A3	-5	1984	0.192	<0.001	160.0	0.055	20.1	0.0019
8A3	-6	1984	0.145	<0.001	165.0	0.055	18.9	0.0015
8A4	1	1984	0.1011	<0.001	92.8	0.080	8.16	0.002
8A4	2	1984	0.094	<0.001	98.6	0.090	7.98	0.002
8A4	3	1984	0.123	<0.001	122.6	0.11	8.16	0.001
8A4	4	1984	0.152	<0.001	126.4	0.10	8.16	0.002
8A4	5	1984	0.161	<0.001	145.0	0.12	8.16	0.002
8A4	6	1984	0.168	<0.001	154.6	0.12	9.05	0.002
8G1	1	1983	0.614	<0.001	446.0	0.36	2.38	0.002
8G1	2	1983	0.509	<0.001	508.0	0.41	2.38	0.002
8G1	3	1983	0.464	0.001	426.0	0.35	2.28	0.002
8G1	-1	1984	0.74	<0.001	420.0	0.41	2.1	0.0025

TABLE H-3. ELECTRIC FIELD INTENSITIES AND MAGNETIC FLUX DENSITIES[1]
Wetland Studies (Page 2 of 4)

Site No.	Meas.[2] Pt.	Meas. Yr.	Transverse E Field (Air), V/M		Longitudinal E Field (Earth), mV/M		Magnetic Flux Density, mG	
			76 Hz	60 Hz	76 Hz	60 Hz	76 Hz	60 Hz
8G1	-2	1984	0.60	<0.001	470.0	0.42	2.2	0.0023
8G1	-3	1984	0.60	<0.001	460.0	0.45	2.2	0.0025
8G1	-4	1984	0.81	<0.001	470.0	0.46	2.1	0.0024
8G1	-5	1984	0.69	<0.001	430.0	0.43	2.1	0.0025
8G1	-6	1984	0.49	<0.001	460.0	0.44	2.0	0.0022
8G1	1	1983	0.303	0.001	291.0	0.30	0.67	0.001
8G2	2	1983	0.335	0.001	322.0	0.36	0.73	0.001
8G2	3	1983	0.270	<0.001	293.0	0.28	0.70	0.001
8G2	-1	1984	--	<0.001	280.0	0.33	0.67	0.0013
8G2	-2	1984	--	<0.001	270.0	0.30	0.67	0.0013
8G2	-3	1984	--	<0.001	280.0	0.32	0.70	0.0013
8G2	-4	1984	0.32	<0.001	260.0	0.29	0.68	0.0014
8G2	-5	1984	0.39	<0.001	280.0	0.32	0.72	0.0013
8G2	-6	1984	0.40	<0.001	300.0	0.34	0.75	0.0014
8M2	1	1983	0.063	<0.001	54.0	0.064	0.554	<0.001
8M2	2	1983	0.075	<0.001	60.0	0.071	0.567	<0.001
8M2	3	1983	0.085	0.001	80.0	0.094	0.556	<0.001
8M2	-1	1984	0.059	<0.002	56.0	0.036	0.55	<0.001
8M2	-2	1984	0.064	<0.001	64.0	0.040	0.55	<0.001
8M2	-3	1984	0.062	<0.001	63.0	0.042	0.55	<0.001
8M2	-4	1984	0.067	<0.001	62.0	0.040	0.55	<0.001
8M2	-5	1984	0.072	<0.001	71.0	0.040	0.56	<0.001
8M2	-6	1984	0.080	<0.001	75.0	0.035	0.56	<0.001
8M3	1	1983	0.018	<0.001	13.5	0.095	0.116	<0.001
8M3	2	1983	0.020	<0.001	19.0	0.120	0.117	<0.001
8M3	3	1983	0.018	<0.001	15.6	0.120	0.112	<0.001
8M3	1	1984	0.024	<0.001	16.76	0.026	0.119	<0.001
8M3	2	1984	0.026	<0.001	16.97	0.023	0.118	<0.001
8M3	3	1984	0.021	<0.001	18.90	0.022	0.120	<0.001

TABLE H-3. ELECTRIC FIELD INTENSITIES AND MAGNETIC FLUX DENSITIES[1]
Wetland Studies (Page 3 of 4)

Site No.	Meas.[2] Pt.	Meas. Yr.	Transverse E Field (Air), V/M		Longitudinal E Field (Earth), mV/M		Magnetic Flux Density, mG	
			76 Hz	60 Hz	76 Hz	60 Hz	76 Hz	60 Hz
8M3	4	1984	0.024	<0.001	19.85	0.026	0.122	<0.001
8M3	5	1984	0.020	<0.001	16.77	0.026	0.120	<0.001
8M3	6	1984	0.020	<0.001	17.88	0.027	0.121	<0.001
8M4	1	1983	<0.001	<0.001	9.7	0.004	0.158	<0.001
8M4	2	1983	0.006	<0.001	5.6	0.001	0.147	<0.001
8M4	3	1983	0.007	<0.001	8.2	0.017	0.093	<0.001
8M4	1	1984	0.013	<0.001	9.99	0.012	0.147	<0.001
8M4	2	1984	0.012	<0.001	10.45	0.013	0.147	<0.001
8M4	3	1984	0.011	<0.001	10.16	0.012	0.146	<0.001
8M4	4	1984	0.012	<0.001	10.09	0.014	0.145	<0.001
8M4	5	1984	0.014	<0.001	9.97	0.013	0.145	<0.001
8M4	6	1984	0.013	<0.001	10.05	0.014	0.145	<0.001
8C2	1	1983	<0.001	<0.001	1.21	0.026	0.024	<0.001
8C2	2	1983	<0.001	<0.001	1.25	0.034	0.023	<0.001
8C2	1	1984	<0.001	<0.001	1.35	0.022	0.025	<0.001
8C2	2	1984	<0.001	<0.001	1.47	0.020	0.025	<0.001
8C2	3	1984	<0.001	<0.001	1.42	0.019	0.025	<0.001
8C2	4	1984	<0.001	<0.001	1.56	0.022	0.025	<0.001
8C2	5	1984	<0.001	<0.001	1.44	0.022	0.024	<0.001
8C2	6	1984	<0.001	<0.001	1.22	0.019	0.025	<0.001
8C3	1	1983	<0.001	<0.001	1.67	0.075	--	--
8C3	2	1983	<0.001	<0.001	1.60	0.077	--	--
8C3	3	1983	<0.001	<0.001	1.76	0.081	--	--
8C3	1	1984	<0.001	<0.001	1.67	0.040	0.022	<0.001
8C3	2	1984	<0.001	<0.001	1.79	0.043	0.022	<0.001
8C3	3	1984	<0.001	<0.001	1.74	0.047	0.023	<0.001
8C3	4	1984	<0.001	<0.001	1.77	0.039	0.023	<0.001
8C3	5	1984	<0.001	<0.001	1.75	0.036	0.021	<0.001
8C3	6	1984	<0.001	<0.001	1.64	0.036	0.023	<0.001

TABLE H-3. ELECTRIC FIELD INTENSITIES AND MAGNETIC FLUX DENSITIES[1]
Wetland Studies (Page 4 of 4)

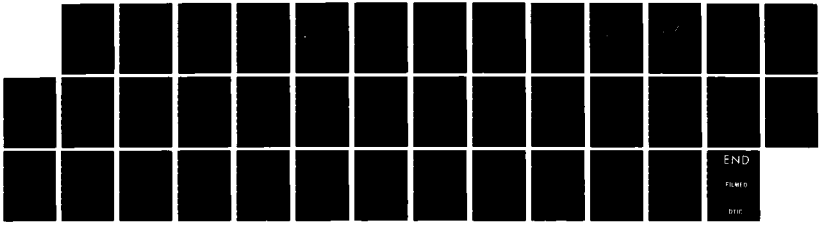
te).	Meas.[2] Pt.	Meas. Yr.	Transverse E Field (Air), V/M		Longitudinal E Field (Earth), mV/M		Magnetic Flux Density, mG	
			76 Hz	60 Hz	76 Hz	60 Hz	76 Hz	60 Hz
;4	1	1984	<0.001	<0.001	1.57	0.009	0.023	<0.001
;4	2	1984	--	--	1.45	0.02	0.024	<0.001
;4	3	1984	--	--	1.42	0.03	0.024	<0.001
;4	1	1984	<0.001	<0.001	1.55	0.05	0.022	<0.001
;4	2	1984	<0.001	<0.001	1.56	0.05	0.022	<0.001
;4	3	1984	<0.001	<0.001	1.47	0.05	0.022	<0.001
;4	4	1984	<0.001	<0.001	1.57	0.05	0.022	<0.001
;4	5	1984	<0.001	<0.001	1.51	0.05	0.021	<0.001
;4	6	1984	<0.001	<0.001	1.57	0.05	0.021	<0.001

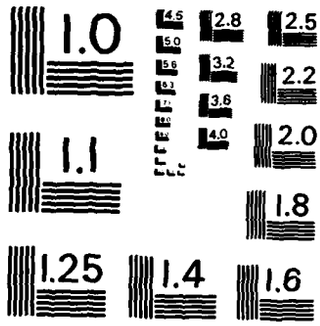
Values shown are magnitudes determined as the square root of the sum of the squares of the orthogonal field components measured.

Measurement point does not necessarily correspond from 1983 to 1984.

AD-A158 360 ELF (EXTREMELY LOW FREQUENCY) COMMUNICATIONS SYSTEM ECOLOGICAL MONITORING..(U) IIT RESEARCH INST CHICAGO IL R M BROSH ET AL. JUN 85 IITRI-E06549-14 2/2

UNCLASSIFIED N00039-84-C-0070 F/G 6/18 NL





MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS - 1963 - A

TABLE H-4. FIELD RATIOS' MAGNITUDE[1]
Wetland Studies

	Transverse E Field (Air)				Longitudinal E Field (Earth)				Magnetic Flux Density			
	R1	R2	R3	R4	R1	R2	R3	R4	R1	R2	R3	R4
T2/C2	>166	>166	>166	1.00	83	351	5910	7.13 -19.47*	292	>4560	7300	1.10 - 1.60
T2/C3	>166	>166	>166	1.00	72	351	2770	3.34 -10.27*	317	>4560	7300	1.10 - 1.60
T2/C4	>166	>166	>166	1.00	82	351	2600	3.14 - 7.40	331	>4560	7300	1.10 - 1.60
T3/C2	>145	>145	>145	1.00	85	2196	6090	2.50 - 3.21	756	>9950	18900	1.20 - 1.90
T3/C3	>145	>145	>145	1.00	74	2196	2850	1.17 - 1.69	821	>9950	18900	1.20 - 1.90
T3/C4	>145	>145	>145	1.00	85	2196	2680	1.10 - 1.22	859	>9950	18900	1.20 - 1.90
T4/C2	> 94	> 94	> 94	1.00	59	773	4220	3.63 - 6.31	319	>3990	>7980	1.00 - 2.00
T4/C3	> 94	> 94	> 94	1.00	51	773	1970	1.70 - 3.33	346	>3990	>7980	1.00 - 2.00
T4/C4	> 94	> 94	> 94	1.00	59	773	1860	1.60 - 2.40	362	>3990	7980	1.00 - 2.00
G1/C2	>490	>490	>490	1.00	269	913	19090	18.63 -24.21*	80	>800	2000	2.20 - 2.50
G1/C3	>490	>490	>490	1.00	234	913	8940	8.72 -12.77*	86	>800	2000	2.20 - 2.50
G1/C4	>490	>490	>490	1.00	267	913	8400	8.20 - 9.20	90	>800	2000	2.20 - 2.50
G2/C2	>320	>320	>320	1.00	166	764	11800	13.18 -17.89*	26	>478	670	1.30 - 1.40
G2/C3	>320	>320	>320	1.00	145	764	5530	6.17 - 9.44	29	>478	670	1.30 - 1.40
G2/C4	>320	>320	>320	1.00	165	764	5200	5.80 - 6.80	30	>478	670	1.30 - 1.40

[1] $R_1 = \frac{T(76\ Hz)}{C(76\ Hz)}$, $R_1 \geq 10$

$R_2 = \frac{T(76\ Hz)}{T(60)}$, $R_2 \geq 10$

$R_3 = \frac{T(76\ Hz)}{C(60)}$, $R_3 \geq 10$

$R_4 = \frac{T(60)}{C(60)}$, $0.1 \leq R_4 \leq 10$.

When a range of values were available for calculating a given ratio, the ratio range was calculated as follows:

High Limit ---> Maximum Numerator Value/Minimum Denominator Value
Low Limit ---> Minimum Numerator Value/Maximum Denominator Value

* Does not meet the exposure criteria.

APPENDIX I

EFFECTS OF ELF ON BIRD MIGRATION STUDIES

EFFECTS OF ELF ON BIRD MIGRATION STUDIES

On 21 May and 24 August 1984, IITRI field crews made ELF EM field measurements at one test site for the effects of ELF on bird migration studies. The position of this site relative to the Republic Transmitter Facility antenna is shown on the composite map in Figure I-1. The site number listed on the map is that used by IITRI. Table I-1 provides a cross reference of IITRI site number, investigator's site name, and township, range, and section number for the site.

TABLE I-1. SITE NO. CROSS REFERENCE

IITRI Site No.	Investigator's Site Name	Location		
		Township	Range	Section(s)
9T1	Radar	T46N	R28W	31

The objective of this study is to examine the relationship between the electromagnetic waves produced by the Republic Transmitter Facility antenna and the migration of birds. The electric and magnetic fields in the air are considered important factors to be examined in bird migration.

Data listed for the magnitude of fields produced by the ELF system were estimated at a frequency of 76 Hz (the expected operating frequency) and based on calculations utilizing the proposed location and operating conditions of the Republic Transmitter Facility antenna elements and the distance to the measurement point. A summary of the measured 60 Hz and estimated 76 Hz data taken at the measurement point for the site is given in Table I-2. These measurements are not the exposures anticipated to free-flying migrant birds and are supplied only to provide an indication of the type of fields in the area of the radar unit. See Reference 3 for a more appropriate estimate of the fields near the ELF antennas.

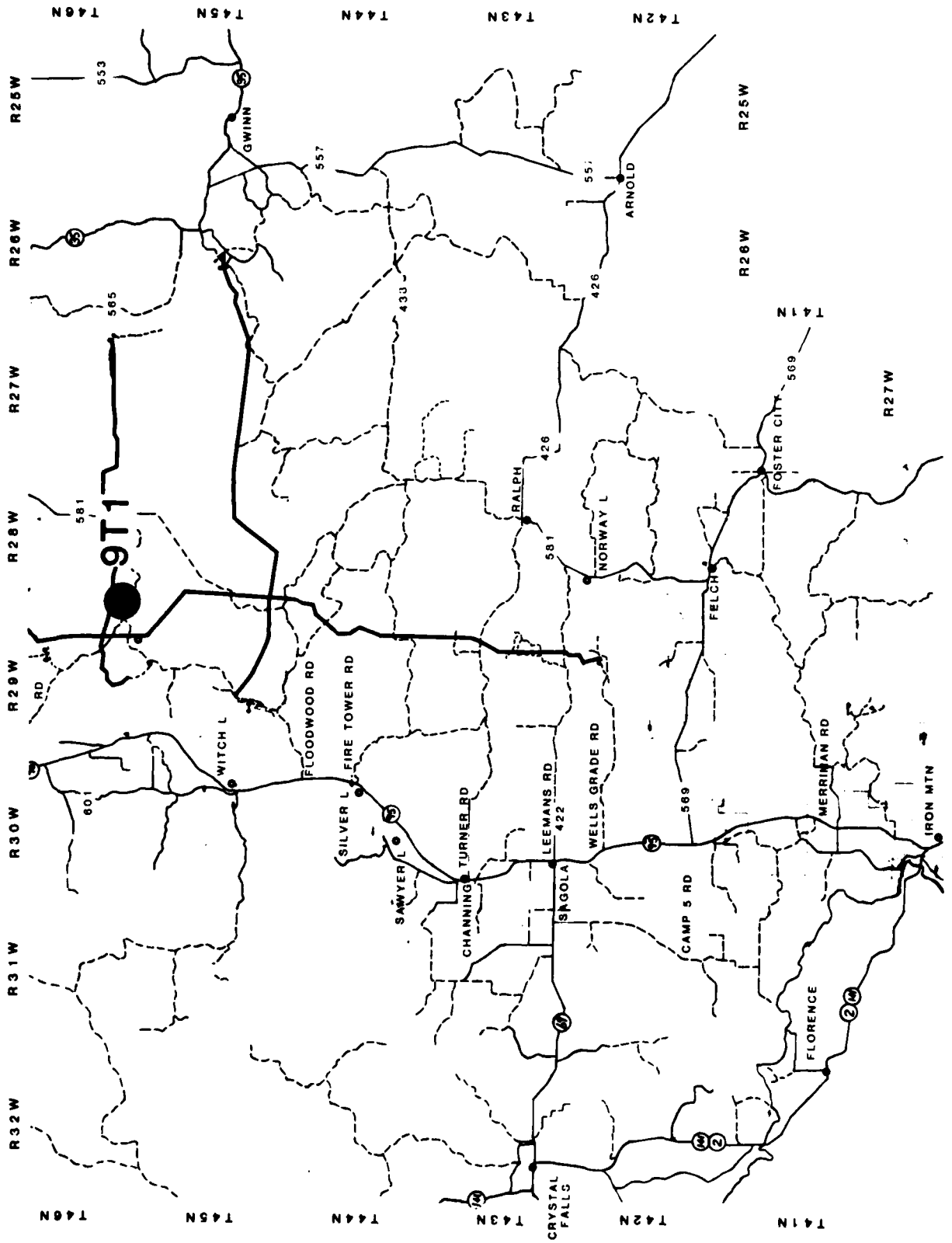


FIGURE I-1. POSITION OF TEST SITE RELATIVE TO TRANSMITTER FACILITY ANTENNA ELEMENTS.

TABLE I-2. ELECTRIC FIELD INTENSITIES AND MAGNETIC FLUX DENSITIES[1,2]
Effects of ELF on Migrating Bird Studies

Site No.	Meas. Pt.	Meas. Pt.	Transverse E Field (Air), V/M		Longitudinal E Field (Earth), mV/M		Magnetic Flux Density, mG	
			76 Hz	60 Hz	76 Hz	60 Hz	76 Hz	60 Hz
9T1	1	1984	0.058	--	30	3.6	0.49	0.001
9T1	1	1984	0.058	--	30	10.7	0.49	0.004

[1] Data listed for 76 Hz is estimated based on analysis using the proposed location and operating conditions of the antenna elements along with the distance to each measurement point.

[2] Values shown are magnitudes determined as the square root of the sum of the square of the orthogonal field components.

APPENDIX J

BIRD SPECIES AND COMMUNITY STUDIES

BIRD SPECIES AND COMMUNITY STUDIES

On 23 and 24 August 1984, IITRI field crews made ELF EM measurements at 10 study transects in Michigan. EM data were taken at 10 transects in Wisconsin on 14, 17, 18, 19, and 21 September 1984. The study of bird species and communities makes use of 20 study transects (five test and five control) in both Michigan and Wisconsin. Eacn transect consists of eight 500 m segments separated by 50 m (i.e., 4350 m or 2.7 miles long). Test transects (prefix 10T) are parallel to and >125 m from the antenna ROW. Control transects (prefix 10C) are variously oriented and are at one-kilometer distances from the antenna.

Transects 10C1 to 10C5 and 10T1 to 10T5 are located in Michigan; the remainder are in Wisconsin. Table J-1 provides a cross reference of IITRI transect numbers, investigator site names, and township, range, and section numbers for the transects in both states. The positions of the 10 transects in Michigan relative to the Republic Transmitter Facility antenna are shown on the composite map in Figure J-1. The positions of the 10 transects in Wisconsin relative to the Wisconsin Transmitter Facility antenna are shown on the composite map in Figure J-2.

The bird species and community studies will monitor migrating bird population using a census technique that involves variable-width transects (procedure outlined by Jarvinen and Vaisanen, 1975). The study will involve monitoring both the total population of migrating birds in an area as a whole and as a species. The electric and magnetic fields in the air are considered the most important EM factors influencing migrating birds; however, the electric field in earth may also have an influence.

Data listed for the magnitudes of the fields produced by the ELF system in Michigan were estimated at a frequency of 76 Hz (the expected operating frequency) and based on calculations utilizing the proposed location and operating conditions of the Republic Transmitter Facility antenna elements and the distance to each measurement point. A summary of the measured 60 Hz and estimated 76 Hz data for 1984 taken at measurements points for each of the sites is given in Table J-2.

TABLE J-1. SITE NO. CROSS-REFERENCE

IITRI Transect No.	Investigator's Site Name	Location		
		Township	Range	Section(s)
		Michigan		
10C1	Carney Lake	41N	29W	33,34,35
10C2	Skunk Creek	42N	28W	14,23,24
		42N	27W	19,30
10C3	Ralph South	43N	28W	12
		43N	27W	7,8,9
10C4	Ralph North	43N	28W	1
		43N	27W	4,5,6
10C5	Arnold	43N	28W	31,32,33,34
10T1	Leeman's Road	43N	29W	14,23,26,35
10T2	Turner Road	43N	29W	1,11,12
		44N	29W	36
10T3	Flat Rock Creek	44N	28W	6
		45N	28W	19,30,31
10T4	Schwartz Creek	45N	28W	31
		45N	29W	26,27,35,36
10T5	Birch Lake	43N	29W	13,24,25
		Wisconsin		
10C6	Spillerberg Lake	43N	3W	23,26,35
10C7	Mineral Lake	44N	4W	9,10,17
10C8	Moose Lake	41N	6W	20,29,32
10C9	Blaiselell Lake	40N	3W	18
		40N	4W	13,14,22,23
10C10	Brunet River	40N	3W	16,21,28
10T6	Moose River	42N	3W	31
		42N	4W	35,36
10T7	Christy Lake	42N	5W	7,8,15,16,17
10T8	Little Clam Lake	42N	4W	5,18,17
		43N	4W	33,32
10T9	Woodtick Lake	43N	4W	22,23,27,28,33
10T10	Black Lake	41N	5W	24,25,36

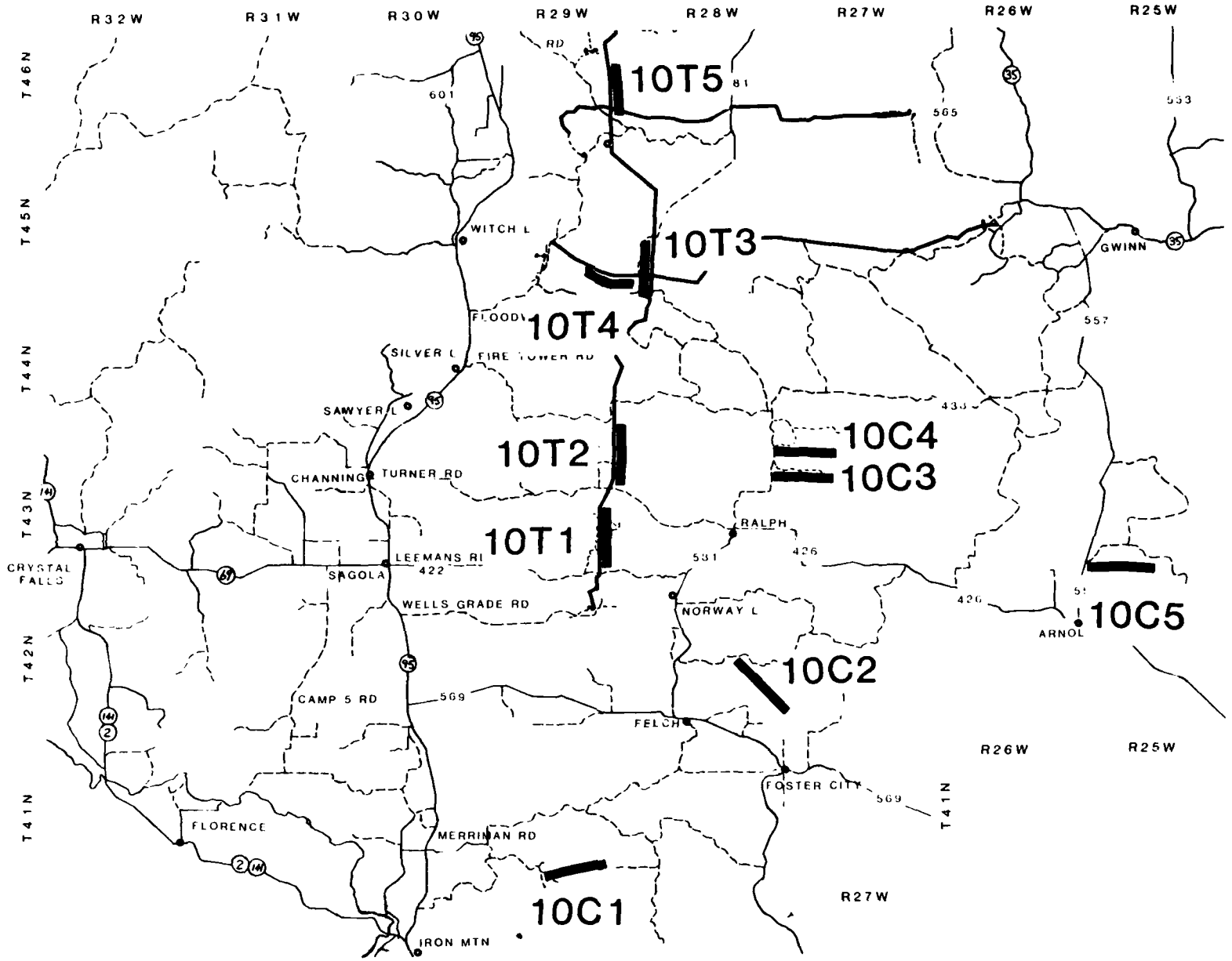


FIGURE J-1. POSITIONS OF MICHIGAN TEST AND CONTROL SITES RELATIVE TO TRANSMITTER FACILITY ANTENNA ELEMENTS.

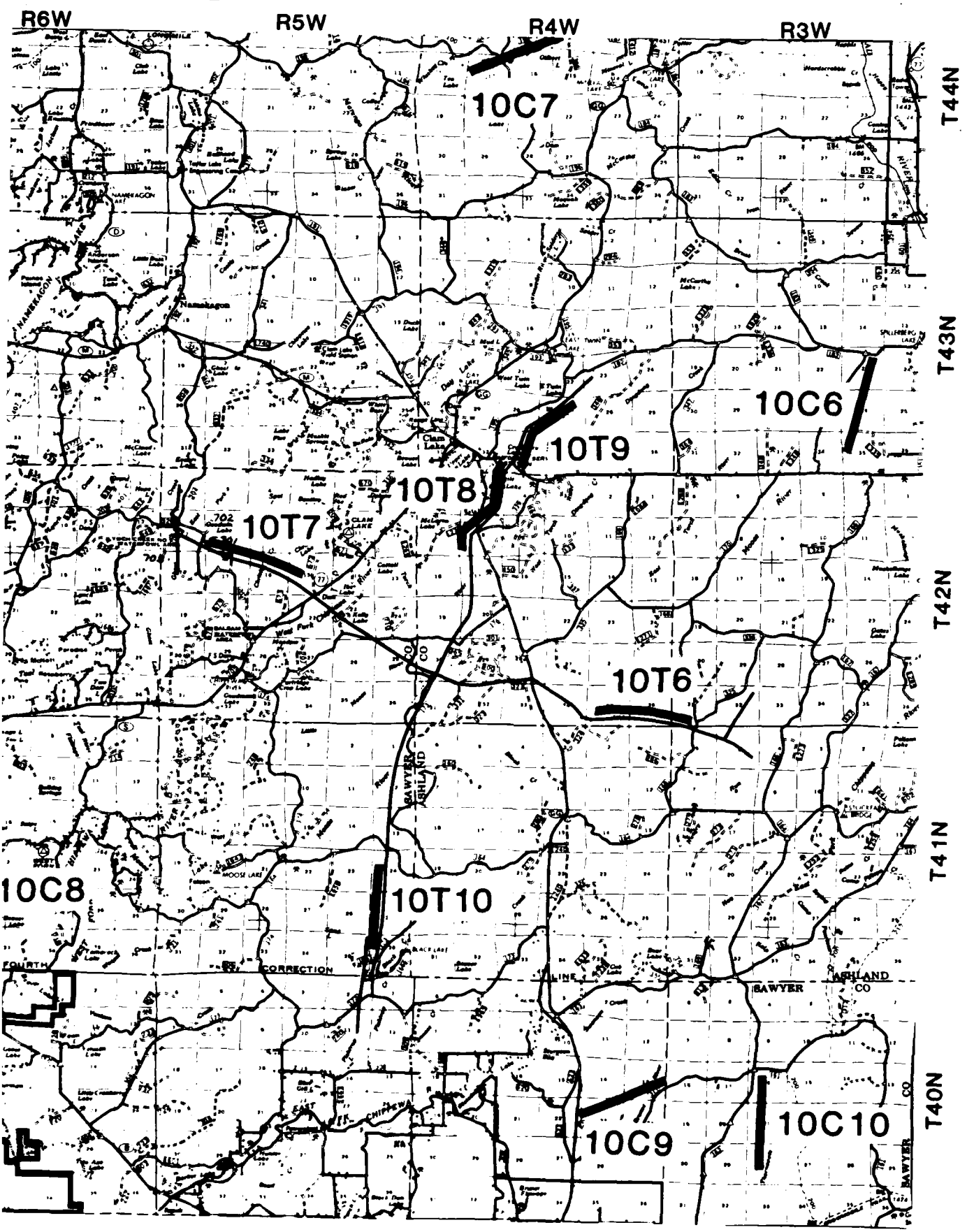


FIGURE J-2. POSITIONS OF WISCONSIN TEST AND CONTROL SITES RELATIVE TO TRANSMITTER FACILITY ANTENNA ELEMENTS.

TABLE J-2. ELECTRIC FIELD INTENSITIES AND MAGNETIC FLUX DENSITIES[1,2]
Bird Species and Community Studies
Michigan Transects

Site No.	Meas. Pt.	Meas. Yr.	Transverse E Field (Air), V/M		Longitudinal E Field (Earth), mV/M		Magnetic Flux Density, mG	
			76 Hz	60 Hz	76 Hz	60 Hz	76 Hz	60 Hz
10C1	1	1984	<0.001	--	0.50	0.61	0.025	0.011
10C1	2	1984	<0.001	--	0.50	0.62	0.025	0.001
10C2	1	1984	<0.001	--	2.0	0.98	0.036	0.005
10C2	2	1984	<0.001	--	1.0	0.35	0.028	0.003
10C3	1	1984	<0.001	--	4.5	0.09	0.038	<0.001
10C3	2	1984	<0.001	--	3.0	0.02	0.026	<0.001
10C4	1	1984	<0.001	--	6.0	0.06	0.038	<0.001
10C5	1	1984	<0.001	0.34	0.50	1.40	0.009	0.56
10C5	2	1984	<0.001	--	0.50	0.35	0.009	0.008
10C5	3	1984	<0.001	--	0.50	0.11	0.008	0.001
10T1	1	1984	0.05-0.5	--	48.0	0.08	2.5	0.006
10T1	2[a]	1984	0.05-0.5	--	48.0	0.08	2.5	0.006
10T2	1[b]	1984	0.05-0.5	<0.001	48.0	0.42	2.5	0.002
10T2	2[c]	1984	0.05-0.5	--	48.0	0.22	2.5	<0.001
10T2	3[d]	1984	0.05-0.5	<0.001	48.0	0.27	2.5	<0.001
10T3	1	1984	0.05-0.5	--	48.0	0.30	2.5	<0.001
10T3	2	1984	0.05-0.5	--	48.0	0.26	2.5	<0.001
10T4	1	1984	0.05-0.5	--	48.0	0.29	2.5	<0.001
10T4	2	1984	0.05-0.5	--	48.0	0.45	2.5	<0.001
10T5	1	1984	0.05-0.5	--	48.0	1.17	2.5	0.002
10T5	2	1984	0.05-0.5	--	48.0	0.34	2.5	0.003

[1] Data listed for 76 Hz is estimated based on analysis using the proposed location and operating conditions of the antenna elements along with the distance to each measurement point.

[2] Values shown are magnitudes determined as the square root of the sum of the square of the orthogonal field components.

[a] 1984 data for site 1T1-1.

[b] 1984 data for site 1T5-1.

[c] 1984 data for site 1T4-2.

[d] 1984 data for site 3T2.

Data listed for the magnitudes of the fields produced by the ELF system in Wisconsin were determined as the square root of the sum of the squares of the orthogonal field components measured. Data for 76 Hz represent worst case values determined by summation of the magnitudes of the fields produced by the east-west and north-south antennas at full operating current (300 amperes). Table J-3 presents a summary of the measured 60 and 76 Hz data taken at measurements points for each of the sites.

The ELF EM field exposure criteria were applied to the data by computing the field intensity ratios utilized in the mathematical representation of the exposure criteria (see Section 2.1). The results of this effort are illustrated in Tables J-4 and J-5 for Michigan Wisconsin sites, respectively.

The acceptability of the test/control site pairings for Michigan is shown in Table J-6; Table J-7 shows a similar chart of acceptability for test/control site pairings in Wisconsin.

Table J-8 shows IITRI recommendations for increasing the number of acceptable test/control site pairings. IITRI also recommended replacing control sites 10C3, 10C4, and 10C8 for the 60 Hz exposure, which was inadequate in meeting exposure ratio guidelines. The investigator has adopted the suggestions. The new sites, relocated sites, and original sites still in use will be remeasured in 1985.

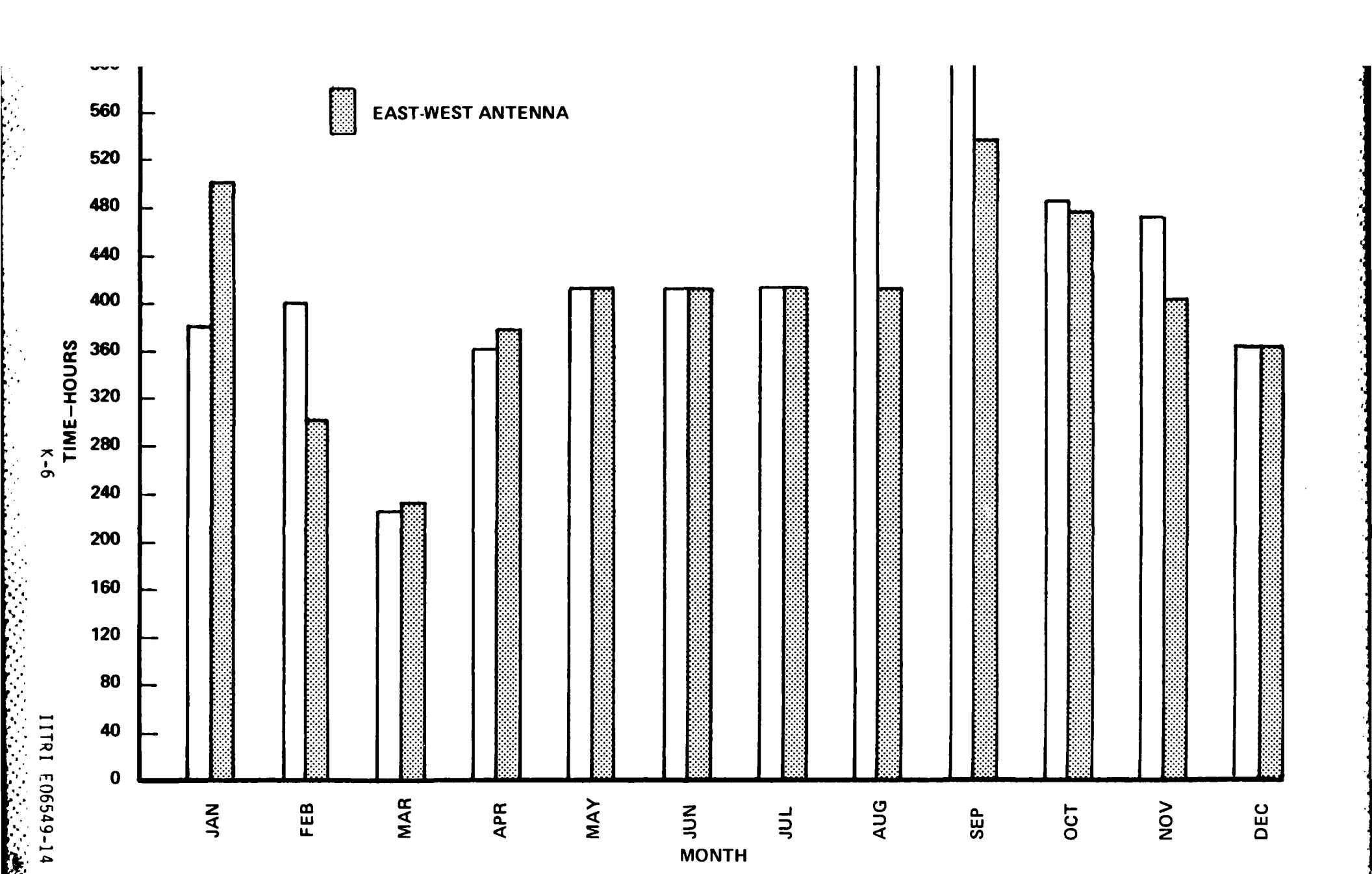


FIGURE K-3. WTF MONTHLY OPERATING TIME SUMMARY, 1984.

IITRI E06549-14

85 229 CC

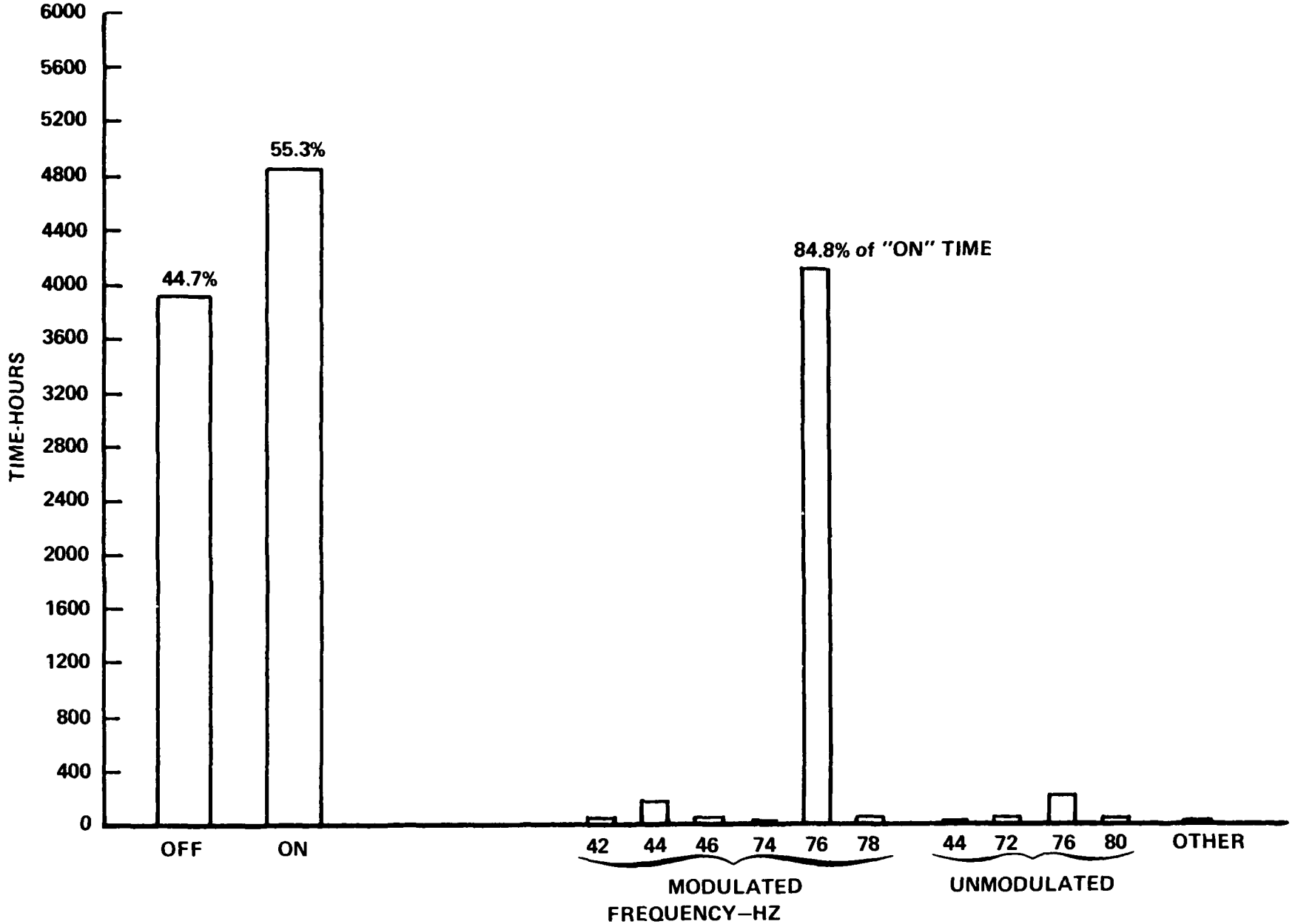


FIGURE K-2. WTF OPERATING SUMMARY, 1984; EAST-WEST ANTENNA.

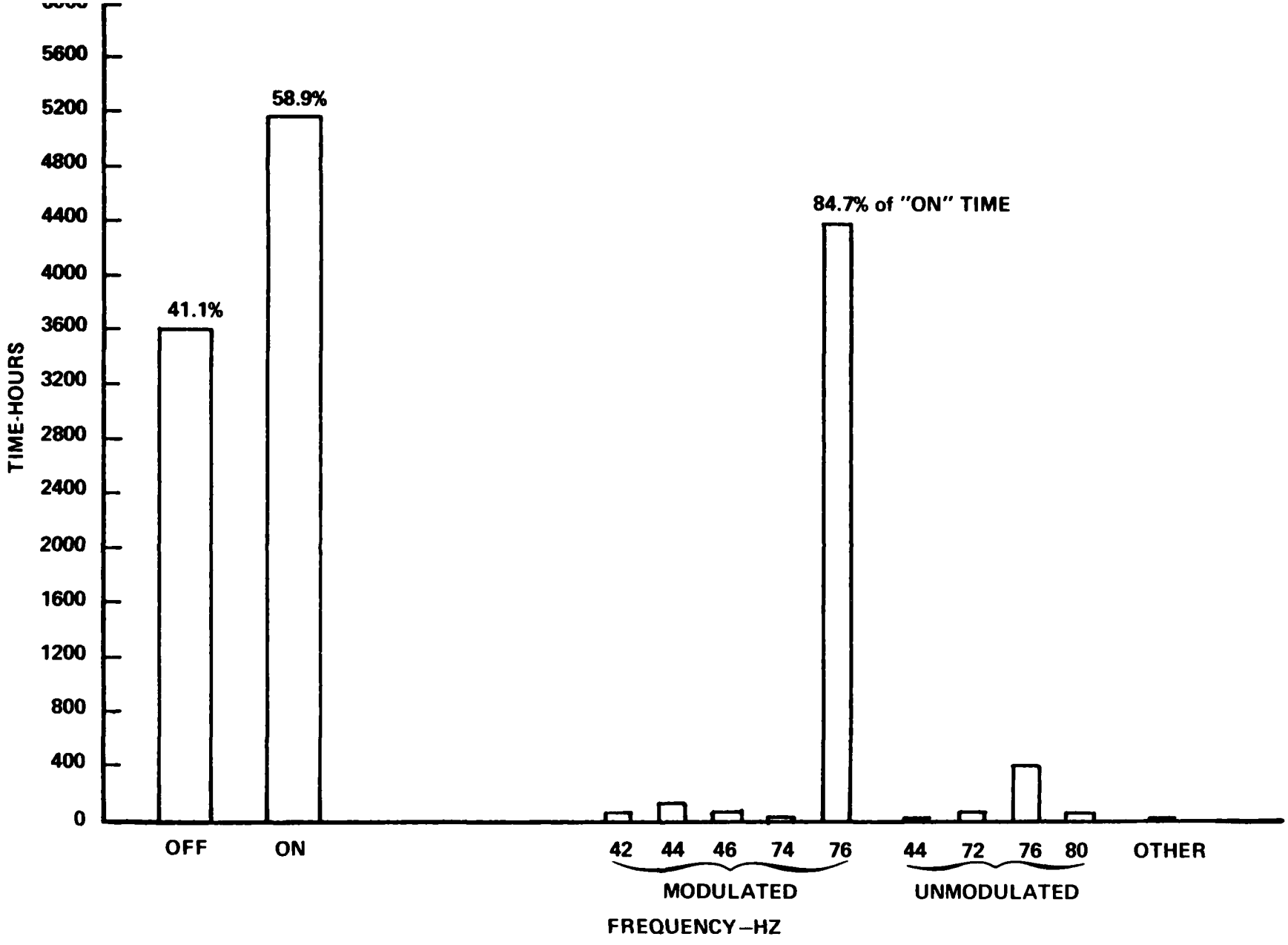


FIGURE K-1. WTF OPERATING SUMMARY, 1984; NORTH-SOUTH ANTENNA.

IITRI E06549-14

85 226 CC

TABLE K-2. WTF OPERATING SUMMARY--1984
East-West Antenna

Frequency, Hz	Hours of Operation per Month												Annual Totals, hr
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
Mode: Modulated Signal[a]													
42										59.7			59.7
44			62.7		1.7				48.4	62.8			175.6
46										59.5			59.5
74										24.4			24.4
76	362.3	288.4	163.9	343.3	379.1	398.7	394.0	349.3	409.0	256.4	418.4	356.1	4118.9
78									43.4				43.4
Subtotal	362.3	288.4	226.6	343.3	380.8	398.7	394.0	349.3	500.8	462.8	418.4	356.1	4481.5
Mode: Unmodulated Signal													
44	27.9			3.5	0.1		0.5		1.8	0.4			34.2
72	14.9	5.8	2.2	4.1	4.3	4.8	2.0	9.2	3.8	2.7	2.7	3.3	59.8
76	96.4	5.7	0.8	4.6	21.2	4.6	11.2	47.3	21.6	6.3			219.7
80	4.7	2.8	0.9	22.1	3.2	2.6	4.2	5.6	5.2	1.2	2.1	1.6	56.2
Subtotal	143.9	14.3	3.9	34.3	28.8	12.0	17.9	62.1	32.4	10.6	4.8	4.9	369.9
Other[b]		3.9	2.9						1.0	1.4			8.6
TOTAL	**506.2**	**302.7**	**233.8**	**377.6**	**412.5**	**410.7**	**411.9**	**411.7**	**534.2**	**474.9**	**423.2**	**361.0**	**4860.0**
Number of Times Powered Up													
	193	121	94	212	564	192	320	615	467	303	140	156	3370

[a] Frequencies listed under "Modulated Signal" refer to the center frequency of modulation.

[b] "Other" denotes very short operation at 40, 48, 68, and 70 Hz or undesignated operation.

TABLE K-1. WTF OPERATING SUMMARY--1984
North-South Antenna

Frequency, Hz	Hours of Operation per Month												Annual Totals, hr
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
Mode: Modulated Signal[a]													
42										59.7			59.7
44			62.7		0.8					62.8			126.3
46										59.5			59.5
74										24.4			24.4
76	367.6	380.9	157.3	344.3	392.2	398.6	392.6	376.2	503.5	256.4	460.1	356.1	4385.8
Subtotal	367.6	380.9	220.0	344.3	393.0	398.6	392.6	376.2	503.5	462.8	460.1	356.1	4655.7
Mode: Unmodulated Signal													
44		1.7	0.05	0.6	0.8		0.6		1.8	0.4			6.0
72	4.8	11.2	2.2	4.1	4.5	4.8	2.0	22.1	3.8	3.0	3.0	3.3	68.8
76	4.0	0.2	0.4	6.5	13.6	6.6	13.0	197.7	137.4	10.6	2.3		392.3
80	5.6	5.8	2.6	5.1	2.2	2.6	2.8	5.6	5.6	3.6	5.1	1.6	48.2
Subtotal	14.4	18.9	5.3	16.3	21.2	14.0	18.4	225.4	148.5	17.6	10.4	4.9	515.4
Other[b]		0.3	0.2	0.6	0.9				0.9	2.7			5.6
TOTAL	**382.0**	**400.1**	**225.7**	**361.2**	**413.8**	**412.6**	**411.0**	**601.6**	**653.0**	**483.2**	**470.5**	**361.0**	**5176.7**
Number of Times Powered Up													
	205	161	98	222	593	219	307	805	554	364	157	156	3841

[a] Frequencies listed under "Modulated Signal" refer to the center frequency of modulation.

[b] "Other" denotes very short operation at 40, 48, 68, and 70 Hz or undesignated operation.

SUMMARY OF WISCONSIN TRANSMITTER FACILITY OPERATION

The operation of the Wisconsin Transmitter Facility (WTF) has been summarized in response to requests from investigators for information on the WTF operating schedule. The summary includes modulated signal operation, unmodulated signal operation, and number of times the antenna was powered up.

Table K-1 shows the hours of operation per month for the north-south antenna; Table K-2 does the same for the east-west antenna. The columns titled "Hours of Operation per Month" show subtotals and totals for hours that the antenna operated in the modes specified. The "Annual Totals" column shows the total number of hours the antenna operated in a designated mode during 1984. The last row of each table gives the number of times the antenna was powered up for the year.

The tables are presented in graph form in Figures K-1, K-2, K-3, and K-4.

APPENDIX K

SUMMARY OF WISCONSIN TRANSMITTER FACILITY OPERATION

TABLE J-8. RECOMMENDATIONS FOR RELOCATING EXISTING TRANSECTS

Michigan
Move start of 10C1 about 0.25 miles to east
Move start of 10C5 about 0.5 miles to east
Move start of 10T5 north
Wisconsin
Move start of 10T9(-1) north and closer to ROW
Move start of 10T8 closer to ROW
Move start of 10C7 southwest away from power line present at junction of FR388 and FR187

TABLE J-6. SUMMARY OF SITE PAIRINGS FOR ORIGINAL MICHIGAN EXPOSURES

Sites	10T1	10T2	10T3	10T4	10T5
10C1	A	CA	U	U	A
10C2	U	CA	A	A	A
10C3	A	U	U	U	U
10C4	U	CA	U	CA	U
10C5	U	U	U	U	U

NOTE: A = Acceptable
CA = Conditionally Acceptable
U = Unacceptable

TABLE J-7. SUMMARY OF SITE PAIRINGS FOR ORIGINAL WISCONSIN EXPOSURES

Sites	10T6	10T7	10T8	10T9	10T10
10C6	A	A	A	U	A
10C7	U	U	U	U	U
10C8	U	U	U	U	U
10C9	A	A	A	U	A
10C10	A	A	A	U	A

NOTE: A = Acceptable
CA = Conditionally Acceptable
U = Unacceptable

TABLE J-5. FIELD RATIOS' MAGNITUDE FOR ORIGINAL WISCONSIN DATA[1]
(Page 2 of 2)

Compared:	Transverse E Field (Air)				Longitudinal E Field (Earth)				Magnetic Flux Density			
Site No's.	R1	R2	R3	R4	R1	R2	R3	R4	R1	R2	R3	R4
10T10/10C7	>101	>101	>101	1.000	66	928	96	0.046*-1.800	456	4560	>4560	1.000
10T10/10C8	>101	>101	>101	1.000	11	928	119	0.057*-0.265	169	4560	2280	0.500-1.000
10T10/10C9	>101	>101	>101	1.000	33	928	835	0.400-9.000	97	4560	4560	1.000
10T10/10C10	>101	>101	>101	1.000	33	928	2783	1.333-4.500	147	4560	>4560	1.000

[1] $R_1 = \frac{T(76\ Hz)}{C(76\ Hz)}$, $R_1 \geq 10$

$R_2 = \frac{T(76\ Hz)}{T(60)}$, $R_2 \geq 10$

$R_3 = \frac{T(76\ Hz)}{C(60)}$, $R_3 \geq 10$

$R_4 = \frac{T(60)}{C(60)}$, $0.1 \leq R_4 \leq 10$.

When a range of values were available for calculating a given ratio, the ratio range was calculated as follows:

High Limit ---> Maximum Numerator Value/Minimum Denominator Value
Low Limit ---> Minimum Numerator Value/Maximum Denominator Value

* Does not meet the exposure criteria.

TABLE J-5. FIELD RATIOS' MAGNITUDE FOR ORIGINAL WISCONSIN DATA[1]
(Page 1 of 2)

Compared: Site No's.	Transverse E Field (Air) R1	R2	R3	R4	Longitudinal E Field (Earth) R1	R2	R3	R4	Magnetic Flux Density R1	R2	R3	R4
10T6/10C6	>120	120	>120	1.000	29	2495	998	0.200-0.667	140	3640	3640	1.000
10T6/10C7	>120	120	>120	1.000	79	2495	115	0.023*-0.800	364	3640	>3640	1.000
10T6/10C8	>120	120	>120	1.000	13	2495	143	0.029*-0.118	135	3640	1820	0.500-1.000
10T6/10C9	>120	120	>120	1.000	40	2495	998	0.200-4.000	77	3640	3640	1.000
10T6/10C10	>120	120	>120	1.000	40	2495	3327	0.667-2.000	117	3640	>3640	1.000
10T7/10C6	>170	>170	>170	1.000	44	1530	1530	0.400-1.667	91	2360	2360	1.000
10T7/10C7	>170	>170	>170	1.000	121	1530	176	0.046*-2.000	236	2360	>2360	1.000
10T7/10C8	>170	>170	>170	1.000	19	1530	219	0.057*-0.294	87	2360	1180	0.500-1.000
10T7/10C9	>170	>170	>170	1.000	61	1530	1530	0.400-10.000	50	2360	2360	1.000
10T7/10C10	>170	>170	>170	1.000	61	1530	5100	1.333-5.000	76	2360	>2360	1.000
10T8/10C6	>52	>52	>52	1.000	14	984	492	0.500-0.833	158	2055	4110	1.000-2.000
10T8/10C7	>52	>52	>52	1.000	39	984	57	0.057*-1.000	411	2055	>4110	1.000-2.000
10T8/10C8	>52	>52	>52	1.000	6*	984	70	0.071*-0.147	152	2055	2055	0.500-2.000
10T8/10C9	>52	>52	>52	1.000	20	984	492	0.500-5.000	87	2055	4110	1.000-2.000
10T8/10C10	>52	>52	>52	1.000	20	984	1640	1.667-2.500	133	2055	>4110	1.000-2.000
10T9/10C6	>71	>1.42*	>71	1.000	17	27	588	1.300-36.667*	59	>1530	1530	1.000
10T9/10C7	>71	>1.42*	>71	1.000	47	27	68	0.149-44.000*	153	>1530	>1530	1.000
10T9/10C8	>71	>1.42*	>71	1.000	7*	27	84	0.186-6.471	57	>1530	765	0.500-1.000
10T9/10C9	>71	>1.42*	>71	1.000	23	27	588	1.300-220.000*	33	>1530	1530	1.000
10T9/10C10	>71	>1.42*	>71	1.000	23	27	1960	4.333-110.000*	49	>1530	>1530	1.000
10T10/10C6	>101	>101	>101	1.000	24	928	835	0.400-1.500	175	4560	4560	1.000

TABLE J-4. FIELD RATIOS' MAGNITUDE FOR ORIGINAL MICHIGAN DATA[1]
(Page 2 of 2)

Compared: Site No's.	Transverse E Field (Air)				Longitudinal E Field (Earth)				Magnetic Flux Density			
	R1	R2	R3	R4	R1	R2	R3	R4	R1	R2	R3	R4
T5/C3	>50	>50	>50	1.000	11	41	533	3.778-58.500*	66	833	2500	2.000-3.000
T5/C4	>50	>50	>50	1.000	8*	41	800	5.667-19.500*	66	833	2500	2.000-3.000
T5/C5	>50	>50	0.147*	0.003*-1.000	96	41	34	0.243-10.636*	278	833	4*	0.004*-3.000

[1] $R_1 = \frac{T(76\ Hz)}{C(76\ Hz)}$, $R_1 \geq 10$

$R_2 = \frac{T(76\ Hz)}{T(60)}$, $R_2 \geq 10$

$R_3 = \frac{T(76\ Hz)}{C(60)}$, $R_3 \geq 10$

$R_4 = \frac{T(60)}{C(60)}$, $0.1 \leq R_4 \leq 10$.

When a range of values were available for calculating a given ratio, the ratio range was calculated as follows:

High Limit ---> Maximum Numerator Value/Minimum Denominator Value
Low Limit ---> Minimum Numerator Value/Maximum Denominator Value

* Does not meet the exposure criteria.

TABLE J-4. FIELD RATIOS' MAGNITUDE FOR ORIGINAL MICHIGAN DATA[1]
(Page 1 of 2)

Compared: Site No's.	Transverse E Field (Air)				Longitudinal E Field (Earth)				Magnetic Flux Density			
	R1	R2	R3	R4	R1	R2	R3	R4	R1	R2	R3	R4
10T1/10C1	>50	>50	>50	1.000	96	600	77	0.129-0.131	100	417	227	0.545-6.000
10T1/10C2	>50	>50	>50	1.000	24	600	49	0.082*-0.229	69	417	500	1.200-2.000
10T1/10C3	>50	>50	>50	1.000	11	600	533	0.889-4.000	66	417	2500	6.000
10T1/10C4	>50	>50	>50	1.000	8*	600	800	1.333	66	417	2500	6.000
10T1/10C5	>50	>50	0.147*	0.003*-1.000	96	600	34	0.057*-0.727	278	417	4*	0.011*-6.000
10T2/10C1	>50	>50	>50	1.000	96	114	77	0.355-0.689	100	2500	227	0.091*-1.000
10T2/10C2	>50	>50	>50	1.000	24	114	49	0.224-1.200	69	2500	500	0.200-0.333
10T2/10C3	>50	>50	>50	1.000	11	114	533	2.444-21.000*	66	2500	2500	1.000
10T2/10C4	>50	>50	>50	1.000	8*	114	800	3.667-7.000	66	2500	2500	1.000
10T2/10C5	>50	>50	0.147*	0.003*-1.000	96	114	34	0.157-3.818	278	2500	4*	0.002*-1.000
10T3/10C1	>50	>50	>50	1.000	96	160	77	0.419-0.492	100	2500	227	0.091*-1.000
10T3/10C2	>50	>50	>50	1.000	24	160	49	0.265-0.857	69	2500	500	0.200-0.333
10T3/10C3	>50	>50	>50	1.000	11	160	533	2.889-15.000*	66	2500	2500	1.000
10T3/10C4	>50	>50	>50	1.000	8*	160	800	4.333-5.000	66	2500	2500	1.000
10T3/10C5	>50	>50	0.147*	0.003*-1.000	96	160	34	0.186-2.727	278	2500	4*	0.002*-1.000
10T4/10C1	>50	>50	>50	1.000	96	107	77	0.468-0.738	100	2500	227	0.091*-1.000
10T4/10C2	>50	>50	>50	1.000	24	107	49	0.296-1.286	69	2500	500	0.200-0.333
10T4/10C3	>50	>50	>50	1.000	11	107	533	3.222-22.500*	66	2500	2500	1.000
10T4/10C4	>50	>50	>50	1.000	8*	107	800	4.833-7.500	66	2500	2500	1.000
10T4/10C5	>50	>50	0.147*	0.003*-1.000	96	107	34	0.207-4.091	278	2500	4*	0.002*-1.000
10T5/10C1	>50	>50	>50	1.000	96	41	77	0.548-1.918	100	833	227	0.182-3.000
10T5/10C2	>50	>50	>50	1.000	24	41	49	0.347-3.343	69	833	500	0.400-1.000

TABLE J-3. ELECTRIC FIELD INTENSITIES AND MAGNETIC FLUX DENSITIES[1]
Bird Species and Community Studies
Wisconsin Transects

Site No.	Meas. Pt.	Meas. Yr.	Transverse E Field (Air), V/M		Longitudinal E Field (Earth), mV/M		Magnetic Flux Density, mG	
			76 Hz	60 Hz	76 Hz	60 Hz	76 Hz	60 Hz
10C6	1	1984	--	--	2.70	0.06	0.021	0.001
10C6	2	1984	--	--	3.50	0.10	0.026	<0.001
10C7	1	1984	<0.001	<0.001	1.26	0.87	0.008	<0.001
10C7	2	1984	--	--	0.90	0.05	0.010	<0.001
10C8	1	1984	--	--	6.50	0.34	0.025	<0.001
10C8	2	1984	--	--	7.98	0.70	0.027	0.002
10C9	1	1984	--	--	1.60	0.10	0.047	0.001
10C9	2	1984	--	--	2.52	0.01	0.037	<0.001
10C10	1	1984	--	--	2.52	0.02	0.031	<0.001
10C10	2	1984	--	--	0.61	0.03	0.015	<0.001
10T6	1	1984	0.201	<0.001	136.0	0.04	3.64	<0.001
10T6	2	1984	0.121	0.014	99.8	0.02	7.57	0.001
10T7	1	1984	--	--	200.2	0.04	4.76	0.001
10T7	2	1984	0.170	<0.001	153.0	0.10	2.36	<0.001
10T7	3	1984	0.195	<0.001	179.0	0.10	4.99	0.001
10T8	1	1984	0.052	<0.001	49.2	0.05	4.11	0.002
10T8	2	1984	0.102	<0.001	117.0	0.05	5.40	0.001
10T9	1	1984	0.071	0.050	58.8	2.20	4.13	<0.001
10T9	2	1984	0.474	<0.001	463.5	0.13	1.53	<0.001
10T10	1	1984	0.101	<0.001	83.5	0.04	4.56	0.001
10T10	2	1984	0.201	<0.001	156.5	0.09	4.98	0.001

[1] Values shown are magnitudes determined as the square root of the sum of the squares of the orthogonal field components measured.

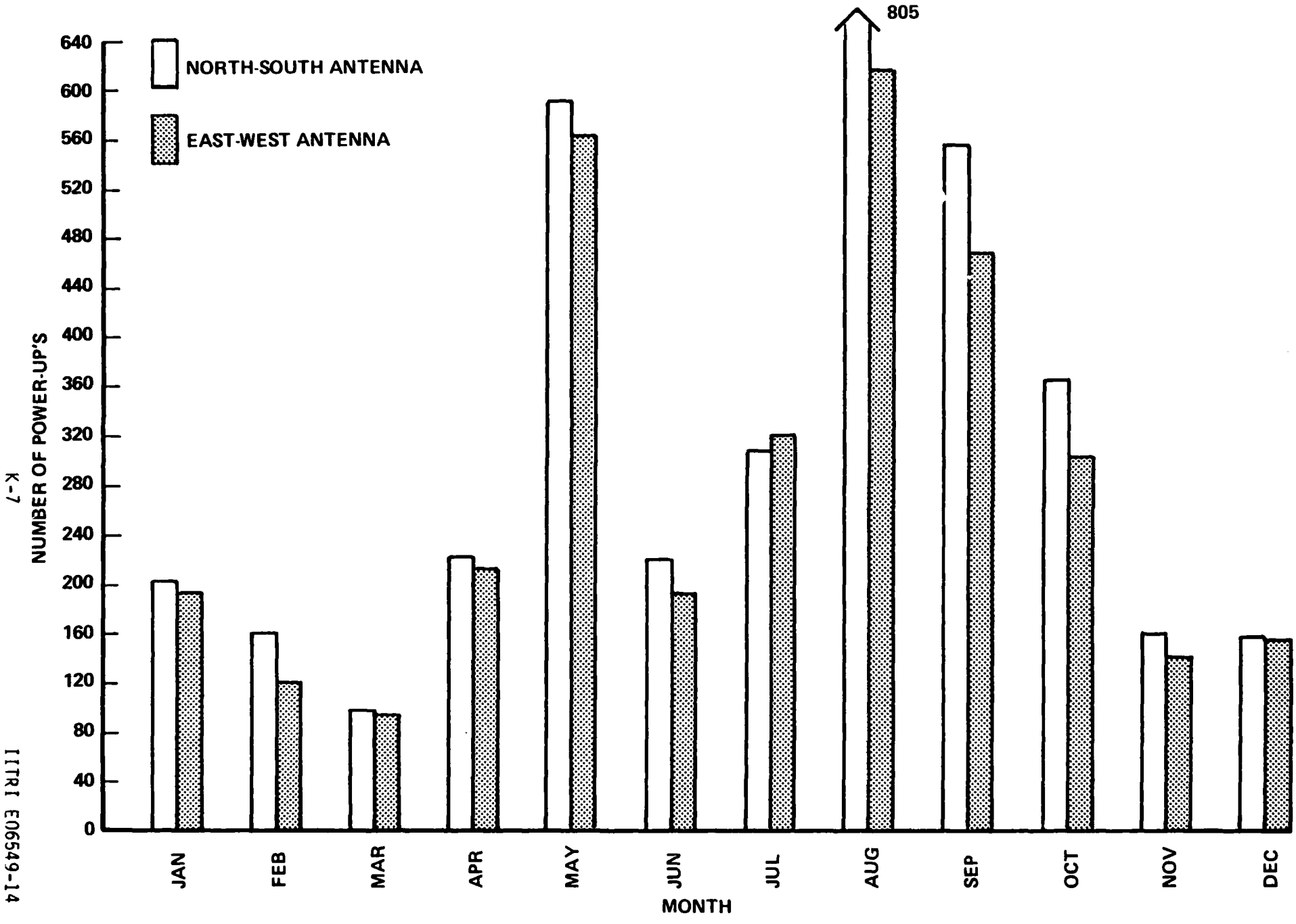


FIGURE K-4. WTF MONTHLY POWER-UP SUMMARY, 1984.

IITRI E06549-14

APPENDIX L

EXPOSURE SETUP PROTOCOLS FOR SOIL AMOEBA AND SLIME MOLD STUDIES

EXPOSURE SETUP PROTOCOLS
FOR SOIL AMOEBA STUDIES

MATCHED E-FIELD PROTOCOL

(1) Measure maximum E-field in soil using 1 meter probe, E.

(2) Multiply E-field value by 0.15 to determine the minimum required drive voltage, V_{DR} (min).

$$V_{DR} \text{ (min)} = E \times 0.15 \text{ (volts)}$$

(3) Locate collector electrodes in line with the maximum E-field in the earth, and spaced far enough apart to generate a voltage across a 2000 ohm resistor that is greater than or equal to V_{DR} (min) (see Figure L-1).

(4) Measure and record electrode spacing and the open circuit (no load) electrode voltage, V_{OC}.

(5) Connect the test cell and monitoring box to the electrodes (see Figure L-2). While monitoring the voltage across the test cell only, V_{CL}, adjust the variable resistor so that the cell voltage is equal to the value given by the following formula:

$$V_{CL} = E \times 0.113 \text{ (volts)}$$

(6) With the cell voltage set, measure and record the voltage across the 100 ohm series resistor, V_R. This allows calculation of the cell current and current density.

(7) Measure and record the electrode voltage with the test cell and monitoring box connected and adjusted as per Step 5, V_{DR}.

MATCHED CURRENT DENSITY PROTOCOL

(1) Measure maximum E-field in soil using 1 meter probe, E.

(2) Locate collector electrodes in line with maximum E-field with a separation of 1 meter.

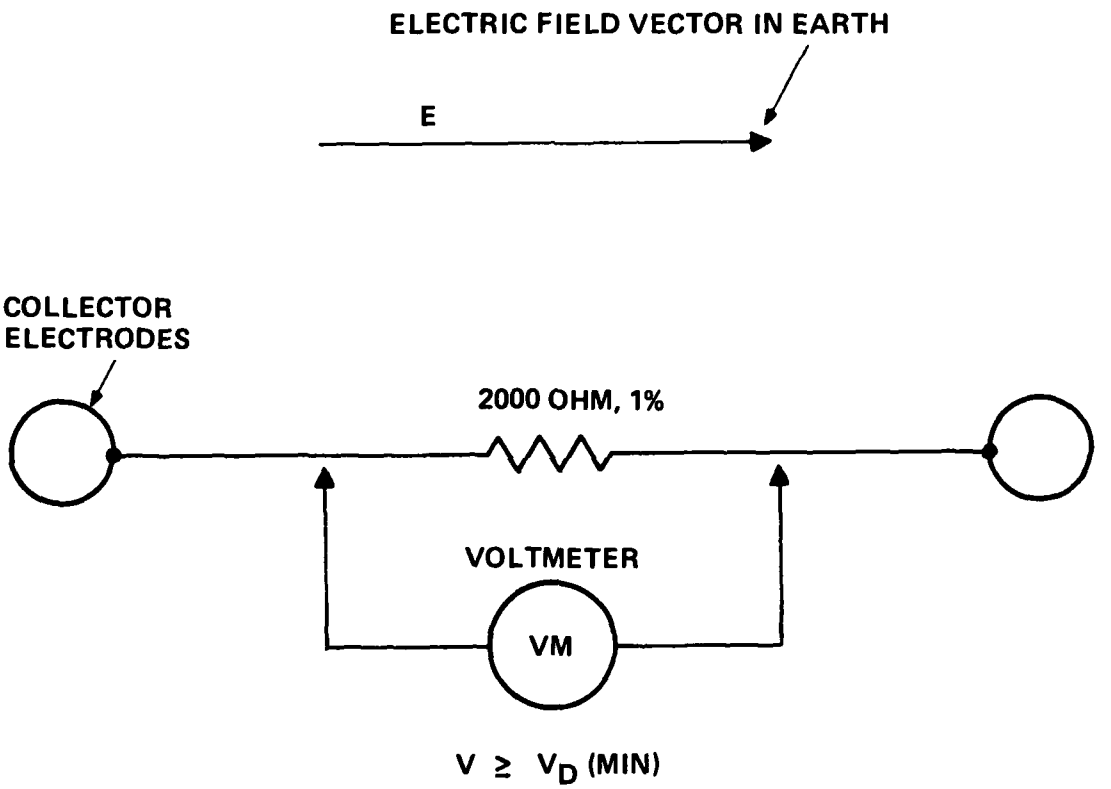
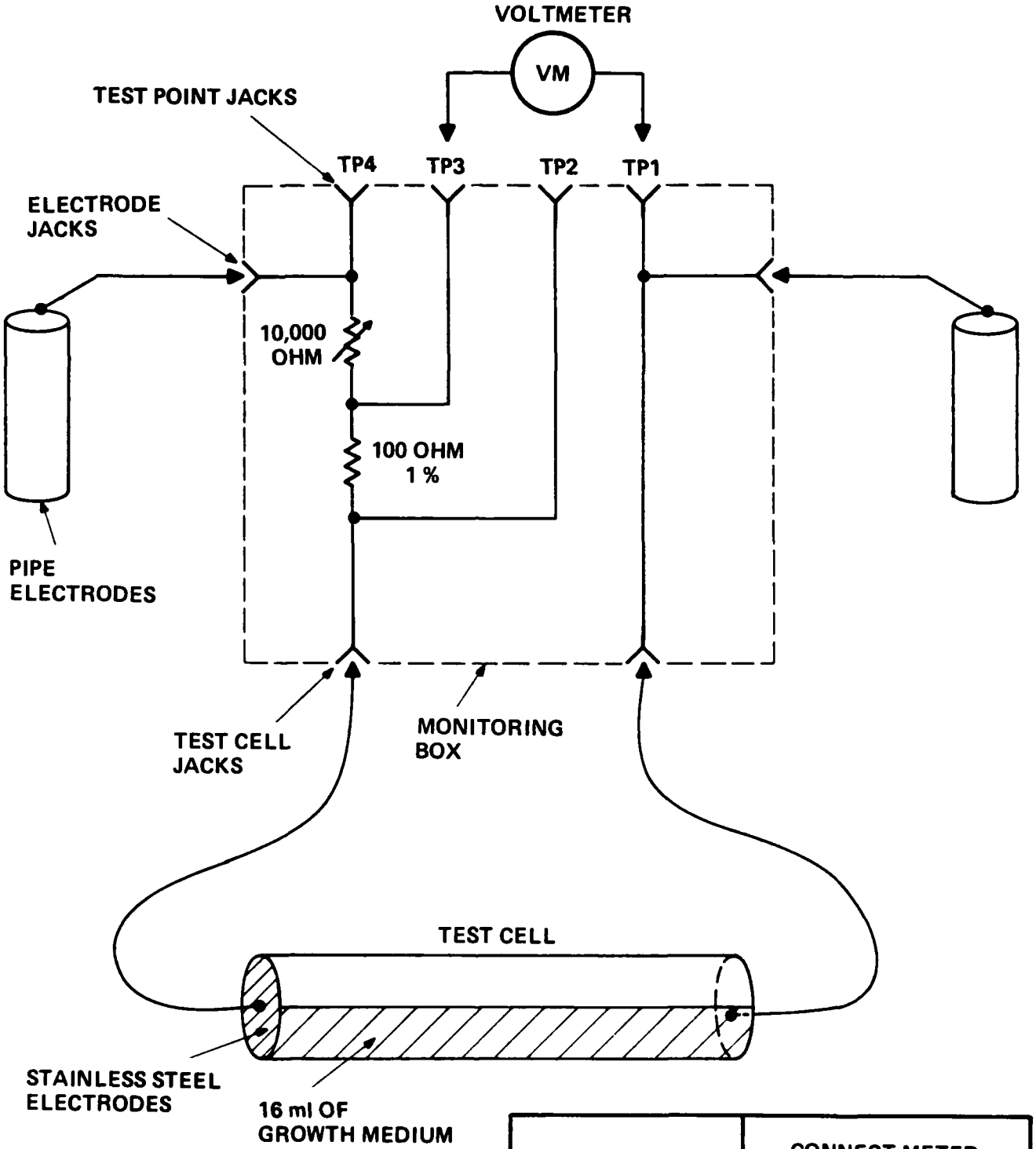


FIGURE L-1. DETERMINATION OF DRIVE VOLTAGE.



TO MEASURE	CONNECT METER ACROSS
V_{CL}	TP1 – TP2
V_R	TP2 – TP3
V_{DR}	TP1 – TP4

FIGURE L-2. TEST CELL HOOKUP FOR MATCHED E-FIELD PROTOCOL.

(3) Measure exact electrode spacing and open circuit (no load) electrode voltage, V^{OC}. Measured voltage should be within a few percent of that measured in Step 1. If not, correct electrode spacing as appropriate.

(4) Connect current-limiting test chamber (see Figure L-3) to electrodes. Place the current limit select switch to the 2.5 megohm position (2.5 M).

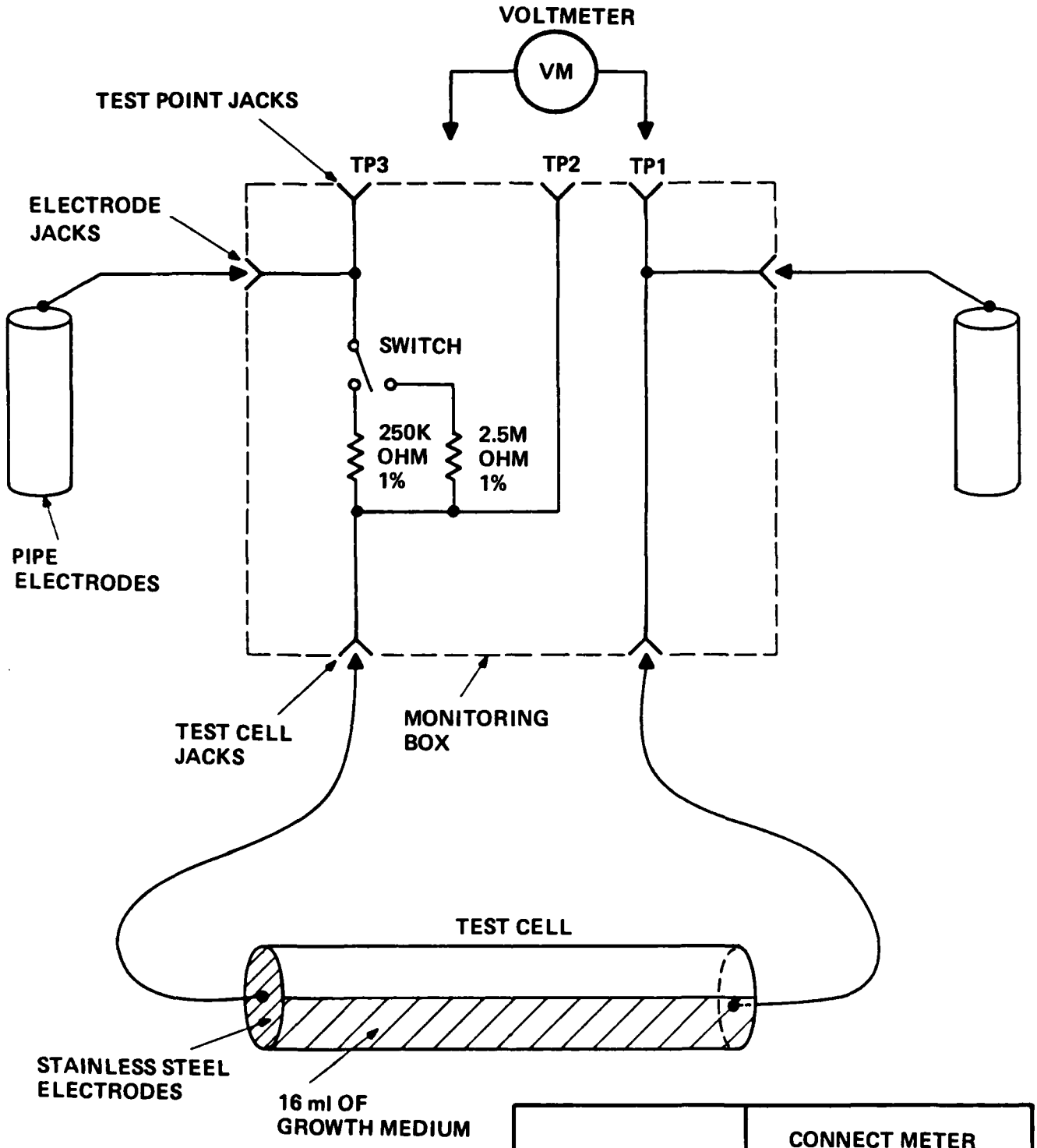
(5) Measure and record the voltages across the test cell, V_{CL} the resistor, V_R and the electrodes, V_{DR}, using the test point jacks (see Figure L-3 for test point numbering).

The voltages across the resistor and across the electrodes should be close in value to V_{OC} from Step 3.

$$V_R \simeq V_{DR} \simeq V_{OC}$$

The voltage across the test cell will be much lower, and can be estimated as:

$$V_{CL} \simeq 0.6 \times 10^{-3} \times V_{OC} \text{ (volts)}.$$



TO MEASURE	CONNECT METER ACROSS
V_{CL}	TP1 – TP2
V_R	TP2 – TP3
V_{DR}	TP1 – TP3

FIGURE L-3. TEST CELL HOOKUP FOR MATCHED CURRENT DENSITY PROTOCOL.

EXPOSURE SETUP PROTOCOLS
FOR SLIME MOLD STUDIES

MATCHED E-FIELD PROTOCOL

(1) Measure maximum E-field in soil with 1 meter probe, E.

(2) Multiply E-field value by 0.2 to determine the minimum required chamber voltage, V_{CH} (min).

$$V_{CH} \text{ (min)} = E \times 0.2 \text{ (volts)}$$

(3) Locate collector electrodes in line with maximum E-field in the earth and spaced far enough apart to generate a voltage across a 1000 ohm resistor that is greater than or equal to V_{CH} (min) (see Figure L-4).

(4) Measure and record electrode spacing and open circuit (no load) voltage, V_{OC}.

(5) Connect test chamber to electrodes. Connect voltmeter to measure voltage across test cell, V_{CL}. Adjust variable resistor (Pot) so that the voltage across the test cell is equal to V_{CL} as determined by the formula:

$$V_{CL} = E \times 0.155 \text{ (volts)}$$

(6) Measure and record the voltage across the 100 ohm series resistor, V_R (see Figure L-5). This allows calculation of the cell current and current density.

(7) Measure and record the voltage between the electrodes with the test chamber connected and adjusted as per Step 5, V_{CH}.

MATCHED CURRENT DENSITY PROTOCOL

(1) Measure maximum E-field in soil using 1 meter probe, E.

(2) Locate collector electrodes in line with maximum E-field with a separation of 1 meter.

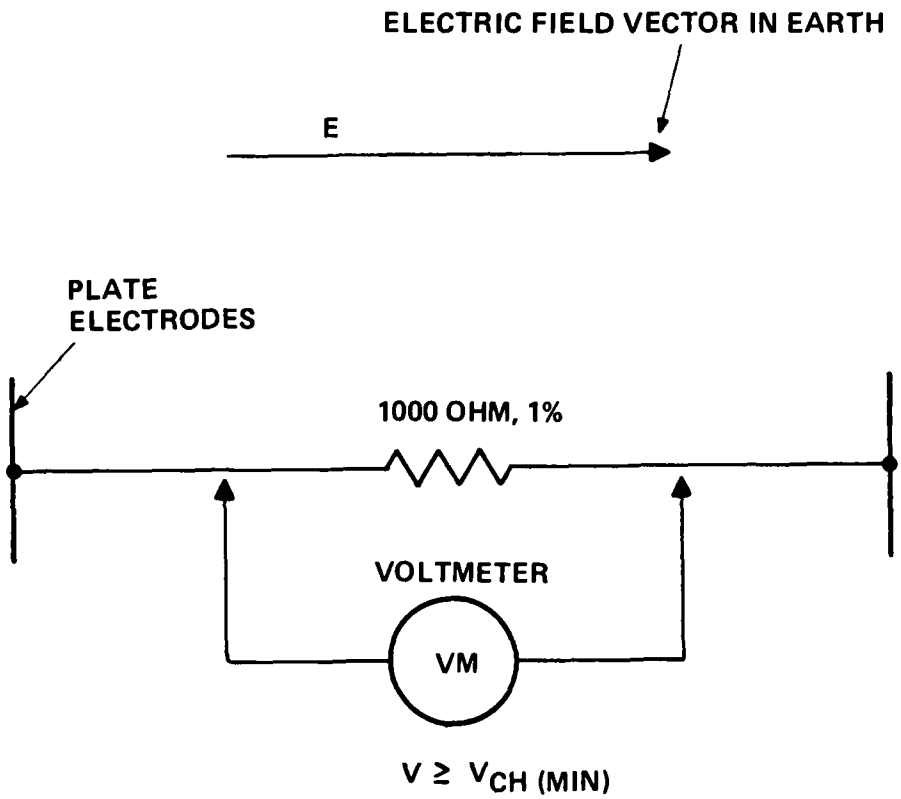
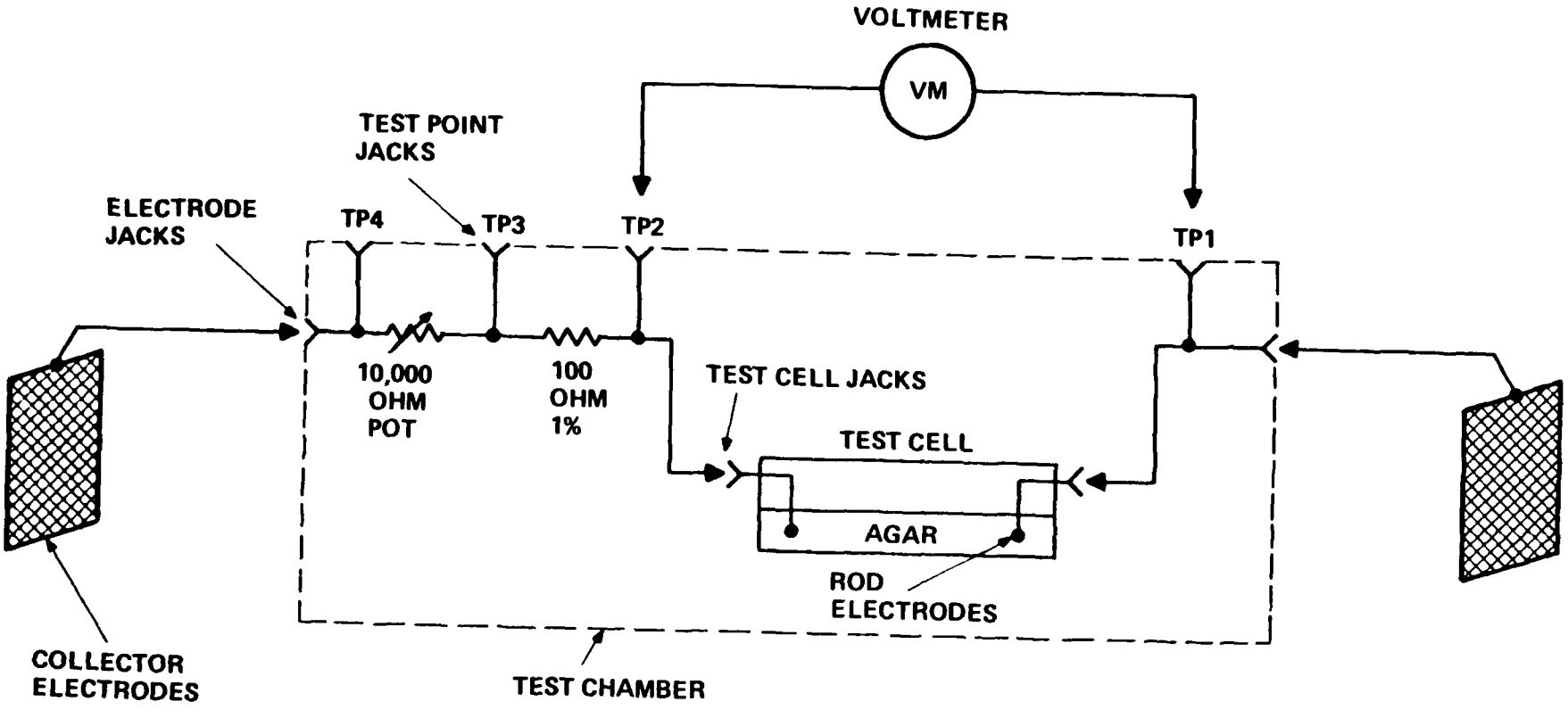


FIGURE L-4. DETERMINATION OF CHAMBER VOLTAGE.



TEST NUMBER	CONNECT VOLTMETER ACROSS
4 V_{OC} 5 V_{CL} 6 V_R 7 V_{CH}	COLLECTOR ELECTRODES TP1 – TP2 TP2 – TP3 TP1 – TP4

FIGURE L-5. TEST CHAMBER WIRING FOR MATCHED E-FIELD PROTOCOL.

(3) Measure exact electrode spacing and open circuit (no load) electrode voltage, V_{OC}. Measured voltage should be within a few percent of that measured in Step 1. If not, correct electrode spacing as appropriate.

(4) Connect current-limiting test chamber (see Figure L-6) to electrodes. Place the current limit select switch to the 500 kilohm position (500 K).

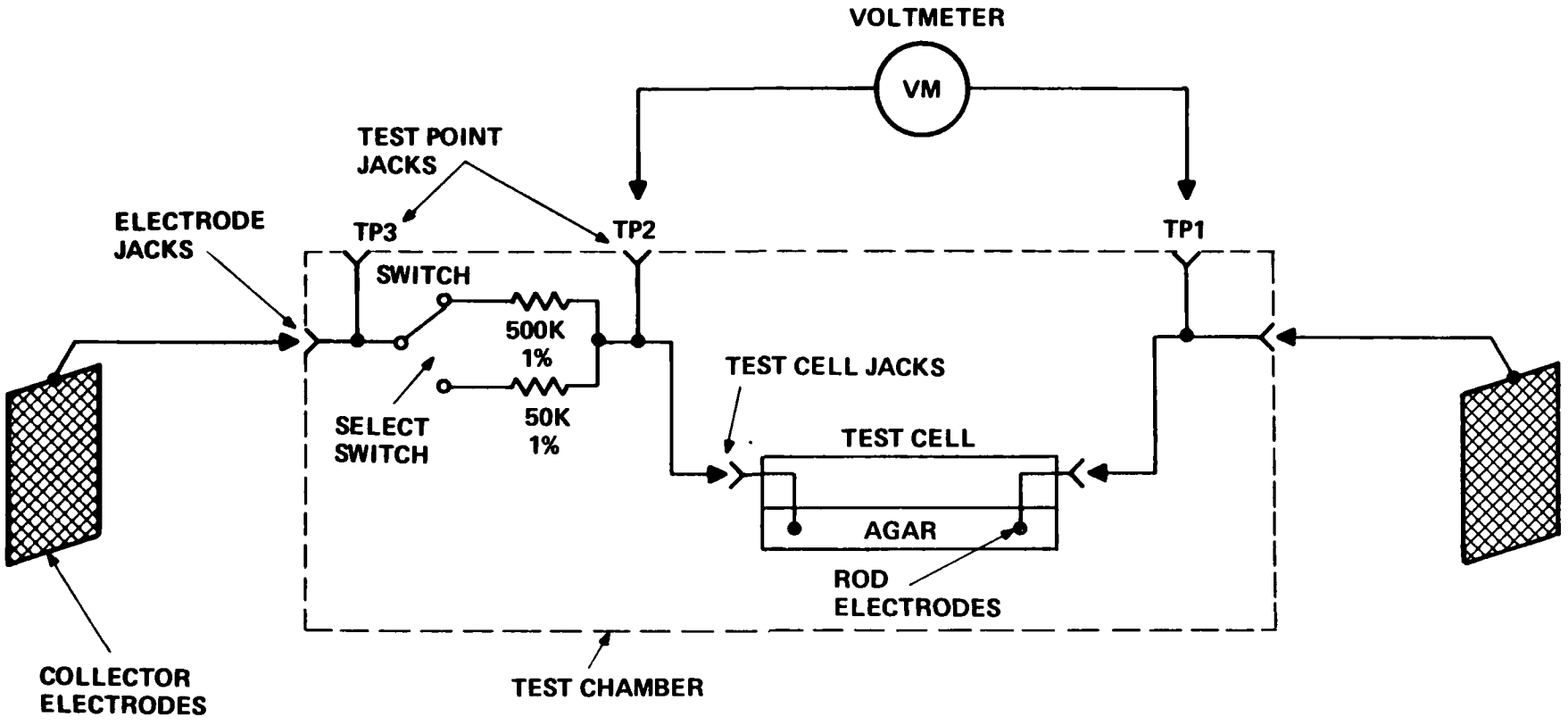
(5) Measure and record the voltages across the test cell, V_{CL}, the resistor, V_R and the test chamber, V_{CH}, using the test point jacks (see Figure L-6 for test point numbering).

The voltages across the resistor and across the test chamber should be close in value to V_{OC} from Step 3.

$$V_R \simeq V_{CH} \simeq V_{OC}$$

The voltage across the test cell will be much lower, and can be estimated as:

$$V_{CL} \simeq 1.6 \times 10^{-3} \times V_{OC} \text{ (volts)}.$$



TO MEASURE VOLTAGE ACROSS	CONNECT VOLTMETER BETWEEN
V_{CL} TEST CELL	TP1 – TP2
V_R RESISTOR	TP2 – TP3
V_{CH} TEST CHAMBER	TP1 – TP3

FIGURE L-6. TEST CHAMBER WIRING FOR MATCHED CURRENT DENSITY PROTOCOL.

IITRI E06549-14

END

FILMED

10-85

DTIC